BALDWIN

DIESEL ENGINE MANUAL

DIESEL · ELECTRIC LOCOMOTIVES

THE BALDWIN LOCOMOTIVE WORKS
PHILADELPHIA, U. S. A.

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1000

MANUAL DE-104

ENGINE MANUAL
for
600 SERIES
DIESEL ENGINES

THE BALDWIN LOCOMOTIVE WORKS
PHILADELPHIA, PENNA.

FOREWORD

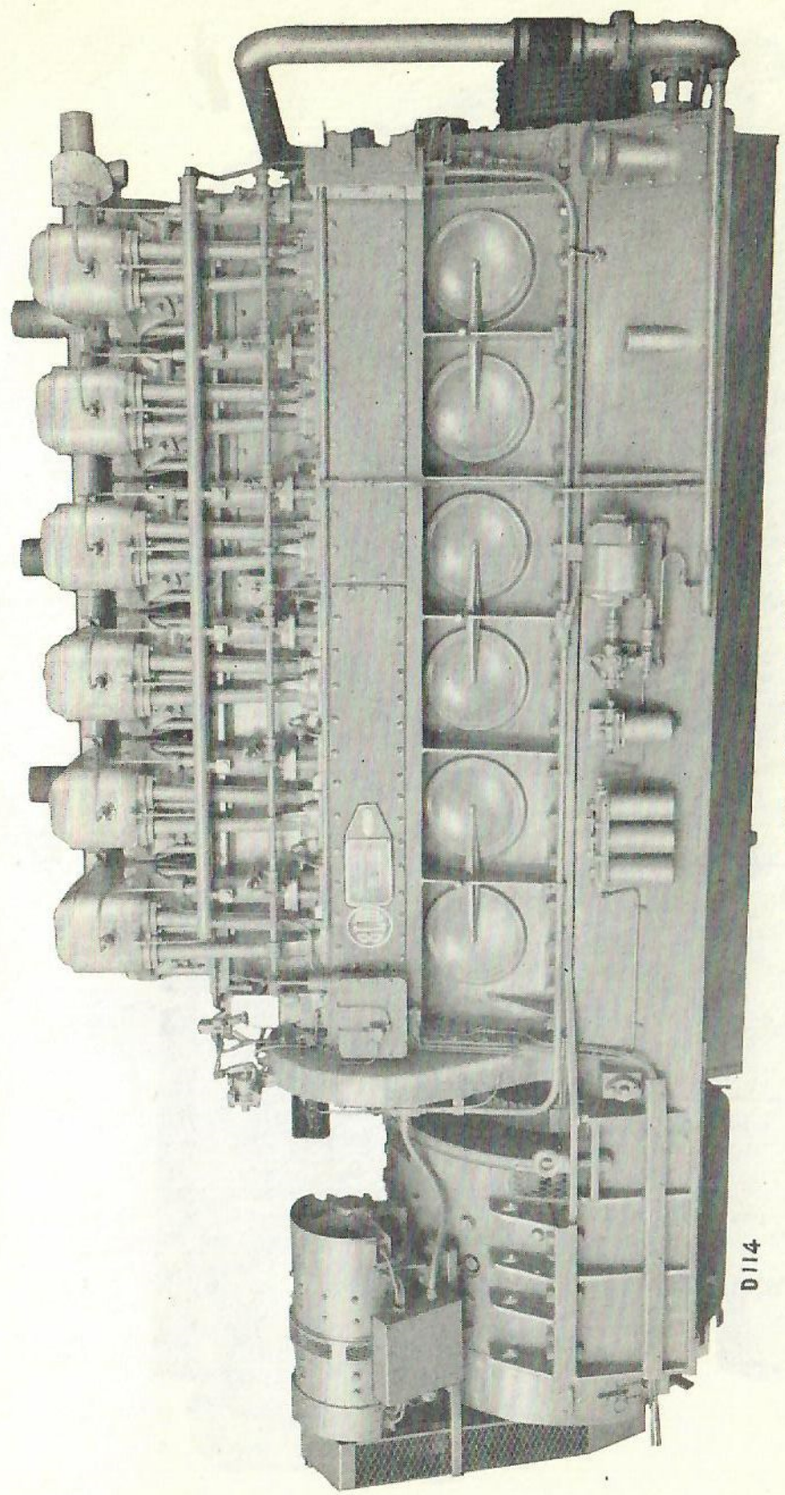
The information contained on the following pages covers the description and maintenance of the 600 series Diesel engines. Certain items on the engine (governor, fuel injection pumps, fuel injectors, turbochargers, etc.) require very careful servicing and adjustment if they are to function properly. If maintenance men experienced with these parts are not available, they should be returned to The Baldwin Locomotive Works or to the manufacturer.

The various parts of the engine are described in separate sections, each containing maintenance instructions concerning the part described. At the end of each section are listed specifications including dimensions and tolerances. Photographs and diagrams are included with the various sections.

The instructions as compiled are suitable for a normally aspirated engine or a supercharged engine. Therefore it will be necessary to use only the information which applies to the particular type of engine involved.

TABLE OF CONTENTS

	PAGE
FOREWORD	1
TABLE OF CONTENTS	2
INDEX TO FIGURES	7
OPERATING DESCRIPTION	9
GENERAL DATA	11
OPERATING ROUTINE	12
ENGINE DIFFICULTIES AND CAUSES	14
BEDPLATE, CRANKSHAFT AND MAIN BEARINGS	101
FRAME	201
CYLINDER LINER	301
PISTONS AND CONNECTING ROD	401
CYLINDER HEAD	501
CAMSHAFT AND CAMSHAFT DRIVE	601
ENGINE TIMING	701
GOVERNOR	801
GOVERNOR CONTROL AND OVERSPEED STOP	901
FUEL INJECTION PUMPS AND INJECTORS	1001
AUXILIARY CHAIN DRIVE	1101
COOLING WATER SYSTEM	1201
FUEL SUPPLY SYSTEM	1301
LUBRICATING OIL SYSTEM	1401
AIR INTAKE FILTER	1501
TURBOCHARGER	1601



MODEL 606 N. A. ENGINE
VALVE GEAR SIDE
Figure 1

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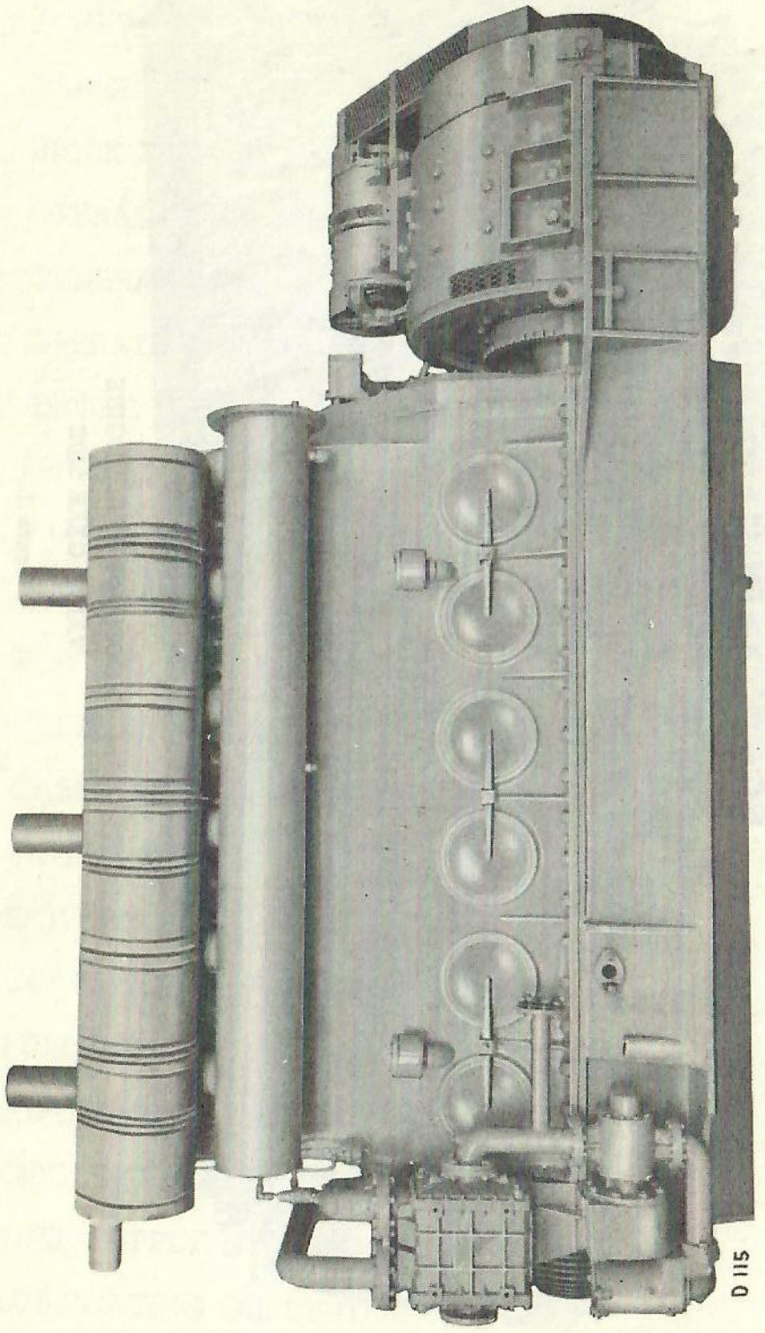

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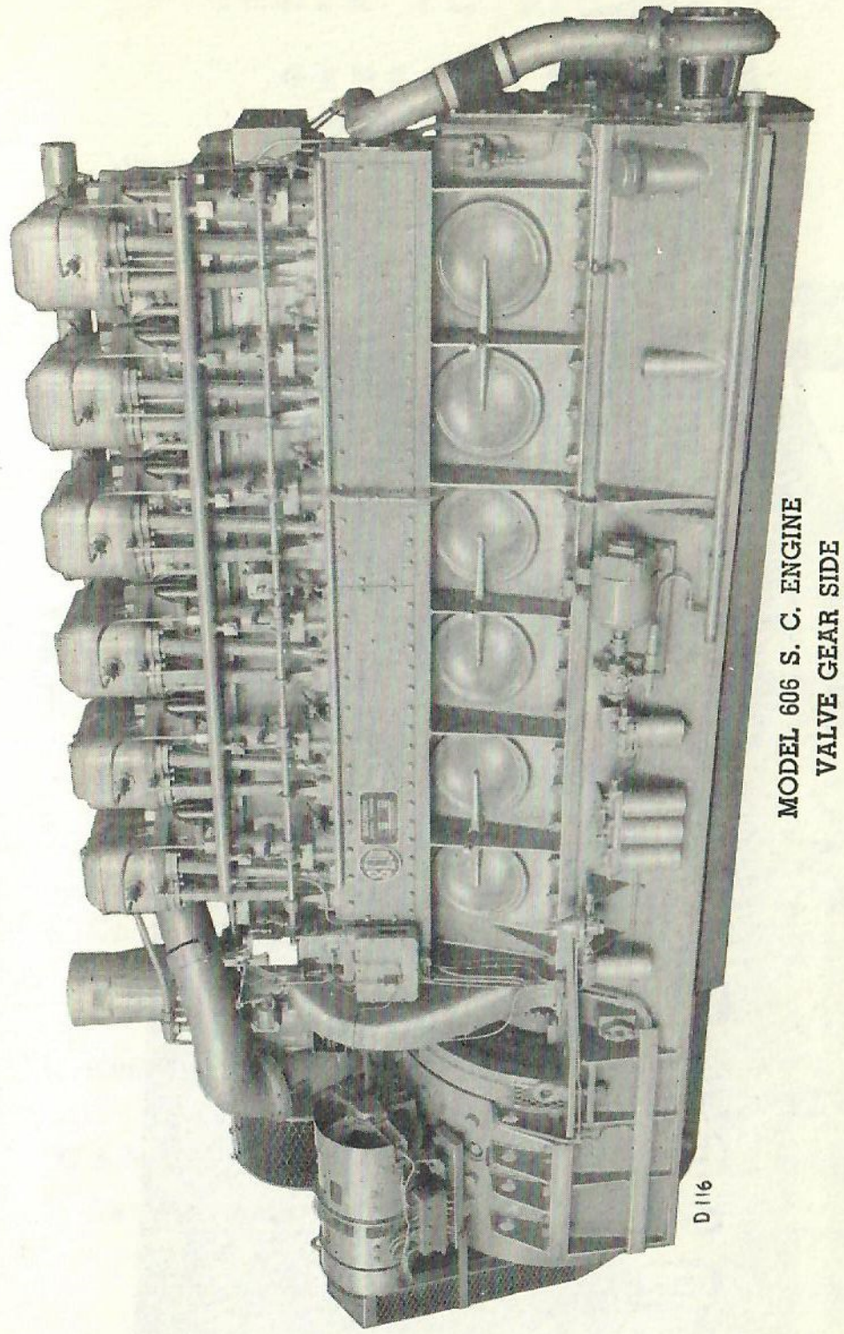
MODEL 606 N. A. ENGINE
EXHAUST SIDE
Figure 2



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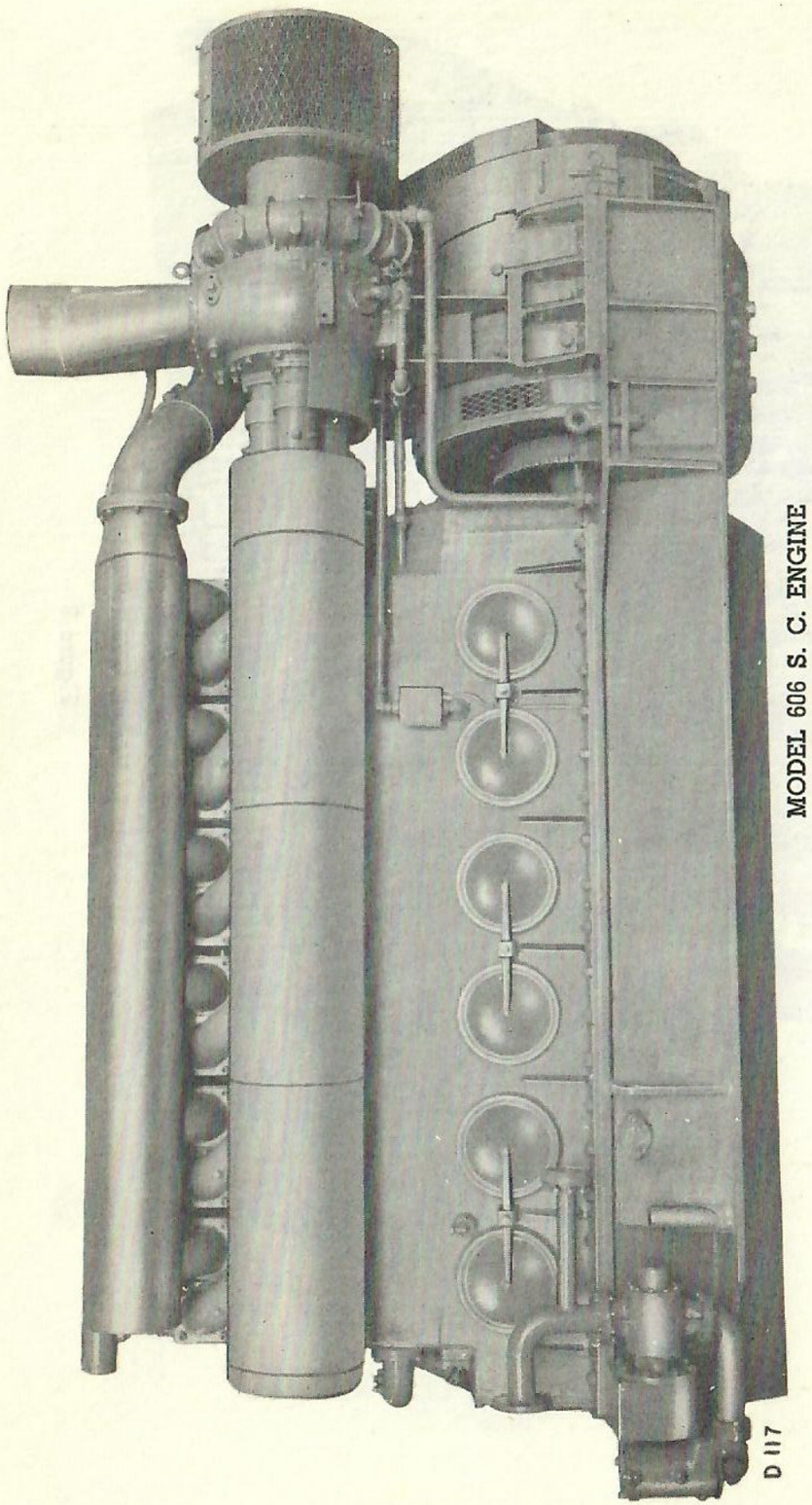
MODEL 606 S. C. ENGINE
VALVE GEAR SIDE
Figure 3



MODEL 606 S. C. ENGINE
EXHAUST SIDE
Figure 4
D 117

INDEX TO FIGURES

GENERAL DATA

Fig.		Page
1.	Model 606 N. A. Engine. Valve Gear Side	3
2.	Model 606 N. A. Engine. Exhaust Side	4
3.	Model 606 S. C. Engine. Valve Gear Side	5
4.	Model 606 S. C. Engine. Exhaust Side	6
5.	Operating Diagram	9
6.	Locations	10

BEDPLATE, CRANKSHAFT AND MAIN BEARINGS

1.	Engine Bedplate	102
2.	Measuring Deflection Between Crank Webs	105
3.	Checking Alignment of Main Bearings	108
4.	Main Bearing	112

PISTON AND CONNECTING ROD

1.	Piston and Piston Ring Clearances	402
2.	Measuring Crank Pin Bearing Clearance	403
3.	Connecting Rod	405

CYLINDER HEAD

1.	Cylinder Head	501

CAMSHAFT AND CAMSHAFT DRIVE

1.	Camshaft Chain Drive	603

ENGINE TIMING

1.	Valve Tappet Adjustment	703
2.	Fuel Pump Inspection Window	704
3.	Fuel Pump	705

GOVERNOR

1.	Governor Section	805

GOVERNOR CONTROL AND OVERSPEED STOP

1. Governor Control 901
2. Setting Overspeed Stop..... 902

FUEL INJECTION PUMPS AND FUEL INJECTOR

1. Operation of Fuel Pump.....1001
2. Fuel Injection Pump.....1003
3. Fuel Injector 1004
4. Balancing Fuel Pump.....1007

AUXILIARY CHAIN DRIVE

1. Auxiliary Chain Drive.....1102

COOLING WATER SYSTEM

1. Water Pump 1203

FUEL SUPPLY SYSTEM

1. Fuel Oil Suction Filter.....1302
2. Fuel Oil Pressure Filter.....1302
2A. Fuel Oil Duplex Filter.....1303
3. Fuel Supply Pump.....1304
4. Engine Fuel Oil System Diagram.....1305

LUBRICATING OIL SYSTEM

1. Lubricating Oil Strainer (Single Unit Type)....1402
2. Lubricating Oil Strainer (Three Unit Type)....1402
3. Lubricating Oil Filter (Circular Type).....1403
4. Lubricating Oil Filter (Flat Type).....1404
5. Low Lubricating Oil Pressure Shutdown Device 1407
6. Lubricating Oil Pump.....1409
7. Engine Sections 1411

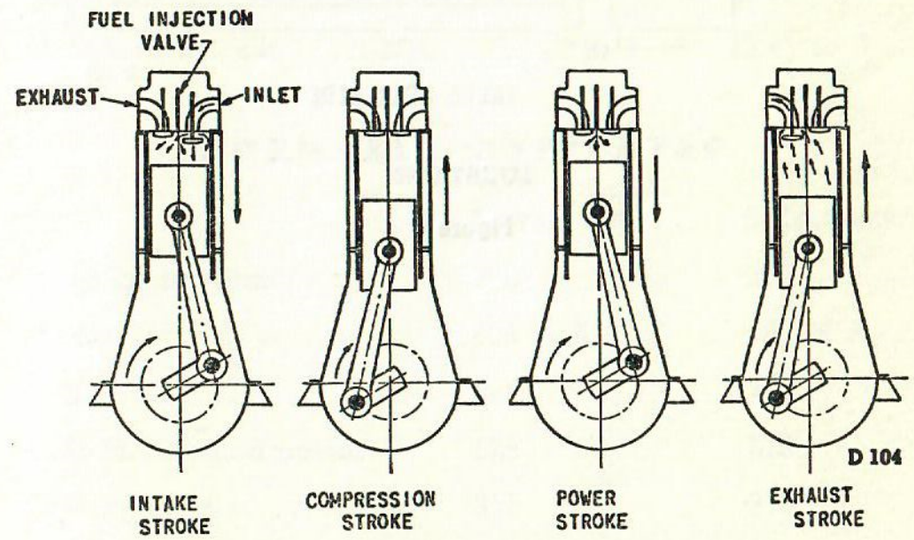
TURBOCHARGER

1. Turbocharger (3 & 4 Exhaust Pipe Type).....1604
2. Turbocharger (2 Exhaust Pipe Type).....1606

OPERATING DESCRIPTION

The Baldwin Diesel engine is a four-cycle vertical in-line engine built as either a 6 cylinder normally aspirated or a 6 or 8 cylinder supercharged model. Separate fuel injection pumps and injectors are provided for each cylinder. All pumps are engine driven with the exception of the fuel oil supply pump which is motor driven.

In a four-cycle engine, there are four strokes of the piston to complete one cycle of events. The piston moves downward on the intake stroke drawing in pure air thru the valves in cylinder head. On the following upward stroke of the piston, this air is compressed, the valves in the cylinder head being closed. Shortly before the piston reaches upper dead center, fuel is injected into this highly compressed air causing it to burn. The resulting expansion of gases forces the piston downward for the power stroke. On the following upward stroke, the burnt gases are expelled thru the exhaust valves. The cycle is then repeated.



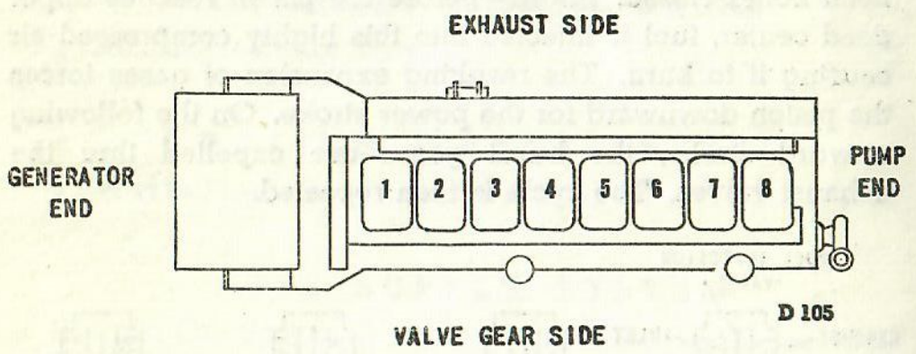
OPERATING DIAGRAM

Figure 5

The turbocharged engine permits a higher output of power than a normally aspirated engine. The energy of the exhaust gas is used to drive a gas turbine which is directly coupled to a centrifugal blower. This blower supplies air to the engine cylinders slightly above atmospheric (approxi-

mately 5½ to 7 pounds). This air scavenges the hot gases from the cylinder and provides a charge of air of higher density and pressure. This increased amount of fresh air permits combustion of a greater quantity of fuel and consequently a higher output of power.

Fig. 4 illustrates the cylinder locations, sides and ends as referred to in the following pages. Lubricating oil pump, water pump, strainers and filters are located at pump end of engine. Main generator, exciter and auxiliary generator are located at generator end. The direction of rotation is counterclockwise when viewed from the generator end.



LOCATIONS

Figure 6

GENERAL DATA

SUPERCHARGED

	8 Cylinder	6 Cylinder
H. P. for traction	1,500	1,000
Model	608 S. C.	606 S. C.
B. H. P.	1625	1125
R. P. M. at rated power	625	625
R. P. M. at idle	250	315
No. of cylinders	8	6
Bore inches	12¾	12¾
Stroke inches	15½	15½
Firing order	1-4-7-6-8-5-2-3	1-2-4-6-5-3
B. M. E. P.—P. S. I.	130	120
Compression ratio	13.45 to 1	13.45 to 1

NORMALLY ASPIRATED

	6 Cylinder	6 Cylinder
H. P. for traction	750	660
Model	606 N. A.	606 N. A.
B. H. P.	825	750
R. P. M. at rated power	625	625
R. P. M. at idle	315	315
No. of cylinders	6	6
Bore inches	12¾	12¾
Stroke in inches	15½	15½
Firing order	1-2-4-6-5-3	1-2-4-6-5-3
B. M. E. P.—P. S. I.	88	80
Compression ratio	14.88 to 1	13.45 to 1

OPERATING ROUTINE

A. STARTING THE ENGINE FOR THE FIRST TIME OR AFTER A LONG PERIOD OF SHUTDOWN.

1. Clean and recharge the air intake filter if it is dirty.
2. Check lubricating oil, fuel, and water supply.
3. After a long layover, remove the casings of the fuel and lubricating oil strainers and clean the elements thoroughly. Renew the fuel oil and lubricating oil filter cartridges.
4. Pour new lubricating oil on all valve gear.
5. Check the condition of lubrication of all accessories and squirt with a few drops of new lubricating oil if dry.
6. Run the fuel oil supply pump to prime the system. Open the vent on the fuel oil filter.
7. Check the cylinder bores, and if dry, squirt with new oil when the piston is at the top position.
8. Bar the engine over several complete revolutions. This will also prime the fuel pumps and injectors.
9. Start the engine and operate at idling speed for ten minutes. Shut the engine down and check all bearings and pistons for lubrication and temperature.
10. If conditions are satisfactory, operate the engine under light load for a half an hour. Shut down and inspect again before putting the engine into normal service. Pay close attention to all pressure and temperature gauges while engine is running.

B. OPERATING ROUTINE AFTER A PARTIAL OR COMPLETE OVERHAUL.

1. When starting the engine after having installed new parts, such as piston, piston rings, piston pins, cylinder liners or bearings, check the condition of lubrication thoroughly as outlined in the preceding paragraph, and the same procedure for starting should be followed. The following operating and inspection procedure is recommended.

2. Operate the engine at idling speed for ten minutes and check the temperature and lubrication of all pistons and bearings or other newly installed parts.
3. If conditions are satisfactory, operate the engine under light load for half an hour. Shut the engine down and repeat the above inspection.
4. Operate the engine under normal load for an hour. Shut the engine down and again repeat the inspection.
5. The above "run-in" and inspection procedure should be executed carefully before the locomotive is returned to normal service.

ENGINE DIFFICULTIES AND CAUSES

A. ENGINE DOES NOT TURN WHEN STARTER IS ENERGIZED.

1. Proper starting sequence has not been followed.
2. Main battery switch is open or loose battery connections.
3. Bar or tool left in a place to block the engine from turning.
4. Burned out control fuse (on control switch).
5. Weak battery.

B. ENGINE TURNS BUT DOES NOT FIRE OR DOES NOT CONTINUE TO RUN AFTER RELEASING START BUTTON.

1. Emergency fuel shut-off valve has been tripped.
2. Fuel tank empty.
3. Fuel supply pump not operating properly.
4. Clogged fuel strainer or filter.
5. Fuel system not primed properly.
6. Lubricating oil pressure too low to keep the shut-down switch from operating.
7. Engine overspeed stop has been tripped.
8. Engine shut-down cylinder or solenoid valve not functioning properly.
9. Insufficient oil in governor casing.
10. Engine stop switch off.
11. Emergency engine stop switch off. (If installed.)

C. IRREGULAR OPERATION.

1. Governor not functioning properly because of lack of oil or faulty adjustment.
2. Leak in the fuel suction piping causing air binding of the injectors.
3. Air or water in the fuel system.
4. Sticking or leaking injector valves or fuel injection pump plunger.
5. Sticking or leaking intake or exhaust valves.

6. Broken exhaust or intake valve springs.
7. Dirty or clogged fuel filter or strainer.
8. Insufficient fuel supply pressure because of dirty or faulty adjustment of relief valves or improper functioning of supply pump.
9. Unsuitable fuel oil.
10. Clogged air intake filter.

D. ENGINE OVERHEATS.

1. Low water supply in the system.
2. Dirt or scale deposited in the radiators.
3. Leak in water pump suction line.
4. Water pump not functioning properly.
5. Restrictions in water lines.
6. Engine overloaded.
7. Radiator fans not functioning properly.
8. Shutter control not functioning properly.

E. EXCESSIVE EXHAUST TEMPERATURE.

1. Engine overloaded.
2. Late fuel injection.
3. Fuel injectors or injection pumps not functioning properly.
4. Faulty valve timing.
5. Unsuitable fuel oil.
6. Faulty turbocharger.

F. ENGINE KNOCKS.

1. Too early fuel injection.
2. Faulty fuel injectors.
3. Cylinder head stud nuts not drawn up enough.
4. Loose bearing bolts.
5. Worn bearings.
6. Worn cylinder liners.
7. Unsuitable fuel oil.

G. ENGINE SMOKES.

1. Engine overloaded or some cylinders overloaded because of improper balance of fuel injection pumps.
2. Faulty fuel injectors or injection pumps.

3. Late fuel injection.
4. Improper valve timing.
5. Clogged air intake filter.
6. Leaking exhaust or intake valves.
7. Clogged oil drain holes in wiper ring grooves.
8. Wiper rings not installed properly on piston.
9. Stuck or worn piston rings.
10. Unsuitable fuel oil.
11. Unsuitable lubricating oil.

H. LOW LUBRICATING OIL PRESSURE.

1. Insufficient lubricating oil in the sump.
2. Lubricating oil suction strainer clogged.
3. Lubricating oil pump discharge strainer clogged.
4. Pressure relief valve leaking, set too low, or broken spring.
5. Faulty lubricating oil pump.
6. Leak in lubricating oil system.
7. Heat exchanger clogged.
8. Lubricating oil filters clogged.

I. EXCESSIVE LUBRICATING OIL PRESSURE.

1. Pressure relief valve stuck or set too high.
2. Restriction in lubricating oil piping inside the engine.
3. Lubricating oil too heavy.
4. Lubricating oil temperature below standard operating conditions.

J. ENGINE STOPS.

1. Fuel tank empty.
2. Emergency fuel shut-off valve has been closed.
3. Engine overspeed stop tripped.
4. Lubricating oil pressure has become too low and the shut-down has operated.
5. Water temperature has become too high and the shut-down has operated.
6. Fuel filter or strainer has become clogged.
7. Air or water in fuel lines.
8. Failure of fuel supply pump.
9. Governor not functioning properly.

BEDPLATE, CRANKSHAFT, MAIN BEARINGS

BEDPLATE

DESCRIPTION

The bedplate is a welded steel structure, extending the length of the engine with extensions for supporting the main generator. It forms the lower supporting structure for the engine and functions as a reservoir for the engine lubricating oil.

The bedplate contains cast steel cross girders having integral main bearing saddles for the crankshaft. Fitted steel caps hold the bearing shells in place.

MAINTENANCE

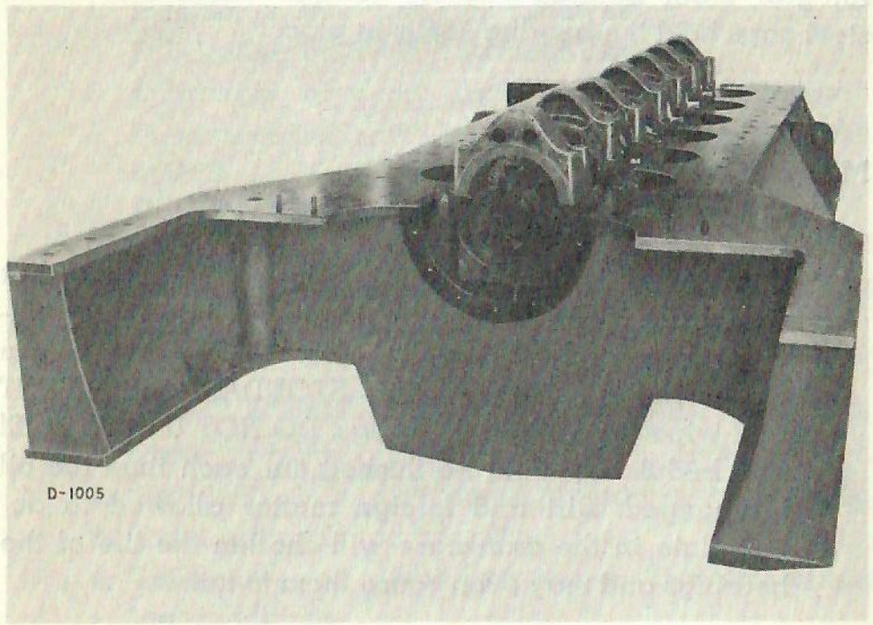
1. Cleaning

If any work is done on the interior of the engine that would allow dirt or metal chips to get into the crankcase, it must be cleaned before the engine is run again. Use a solvent such as STODDARD'S SOLVENT and wipe dry with lintless rags. DO NOT USE WASTE! The bedplate should be flushed out each time the oil is changed. Dirt and foreign matter allowed to accumulate in the crankcase will shorten the life of the bearings and may even cause them to fail.

2. Engine, Painting Instructions

The interior of the engine is painted at the factory with a good grade of crankcase sealer. The spaces so painted include the inside of the bedplate, frame but not water passages or liner, cam trough, and chain drive housing. If these spaces are repainted after an engine overhaul, the surfaces should first be thoroughly cleaned with a caustic solution to remove old paint, sludge, and oil from the surface of the metal. Failure to do this will mean that the paint will peel off and clog up the lubricating oil lines and filters. Machined surfaces such as the bearing bores should not be painted. This applies also to the flanges or surfaces that receive gaskets or seals.

The external surface of the engine (after cleaning) should receive a good coat of primer followed by a coat of enamel. Care should be taken to cover all surfaces that are not to be painted with masking tape such as the fuel pump racks, control shaft springs, name plates, shaft pulleys, etc. In regard to the generator, protect all internal parts and all external wiring that does not have a metallic sheathing.



ENGINE BEDPLATE

Figure 1

SPECIFICATIONS

BEDPLATE

Main and thrust bearing bore diameter.....	10.000" - 10.001"
Length of thrust bearing saddle.....	6.997" - 6.998"
Width of recess in bearing saddles for bearing caps	13.624" - 13.625"

CRANKSHAFT

DESCRIPTION

The crankshaft is of the solid forged type with drilled passages in the crankwebs providing pressure lubrication to the bearings. A flange for bolting the crankshaft to the generator is forged integral with the shaft.

MAINTENANCE

1. Inspection of Shaft

When any main or connecting rod bearings are removed, the crankshaft journals should always be checked for scratches, rough spots, or bearing metal which might have adhered to it. Fine emery paper and oil should be used to remove any of the above items. The rubbing action should be applied in a direction around the journal and not across it. Stoning the journals should *only* be done locally and *only* to remove surface nicks and deep scratches that can not be removed with fine emery paper and oil.

The journals should also be closely checked for cracks. If there is any evidence of cracks in the journal, it should be cleaned with Stoddard's or some other good solvent and thoroughly dried. The presence of a surface crack can readily be determined by applying a coat of ordinary whitewash to the journal surface and allowing it to dry. A surface crack will show as the oil remaining in the crack will discolor the whitewash. A much more preferable method would be to magnaflux the section in question. Under no circumstances should the engine be run if any suspicion remains that there is a crack in the shaft.

2. Removing a Generator

(a) Remove the turbo charger and its air, water and lubricating oil piping which would interfere with the removal of the generator.

(b) Remove the coupling between the air compressor and the generator.

(c) Remove the generator coupling bolts, washers and barring ring. The generator coupling bushings can be pulled into a short length of 3" std. pipe by using a 1½" - 12 Am. Std. thread bolt and several washers.

(d) Remove the bolts, nuts and dowels, securing the generator to the engine bedplate.

(e) Support the generator weight by slings and slide it toward the air compressor until it is free of the flange on the end of the crankshaft. The generator may then be lifted clear of the locomotive.

3. Aligning Generator to Engine

(a) Inspect the mounting faces of the generator armature shaft and the crankshaft. Remove any burrs or rough spots.

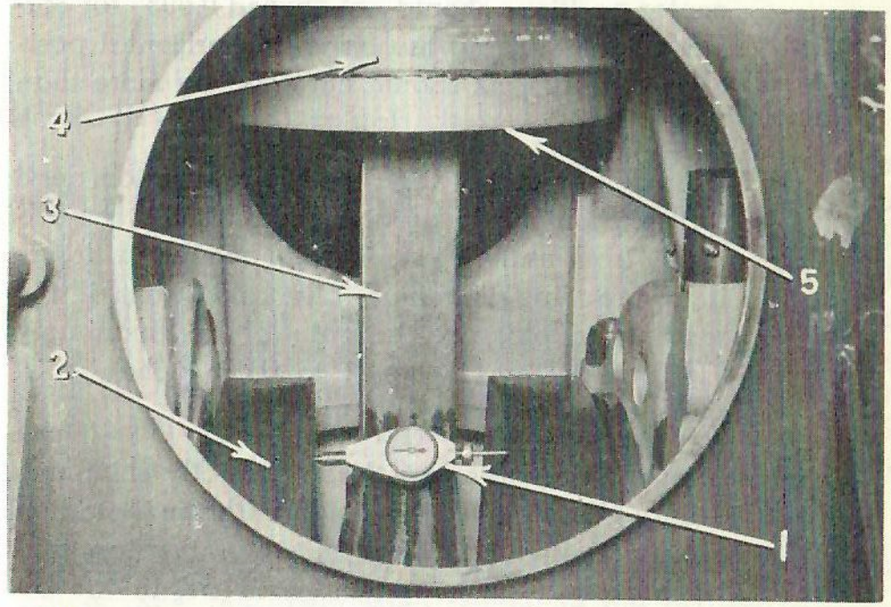
(b) Place a dial indicator on the crankshaft flange face in such a way as to measure its eccentricity in one revolution. This eccentricity or "run out" should not exceed 0.0005" on a 15" diameter. (This step is not necessary when the original generator is applied.)

(c) Place the generator on the bedplate with 0.270 shims underneath each mounting flange. Use the original shims if installing the original generator.

(d) Locate the hole in the generator shaft flange that has the double zero adjacent to it. This is known as its "match mark". Some generators do not have match marks and, if this is the case, this step is not necessary. Locate the hole in the crankshaft flange that is directly opposite #1 throw and rotate the crankshaft until these two holes are in line.

(e) By the use of slings and a hoist move the generator up to the crankshaft and alter its position until the small centering disc on the end of the crankshaft fits into the recess on the end of the generator shaft. Let the weight of the generator then settle on to the engine bedplate and install the generator coupling bushings, bolts, and lockwashers.

(f) Install the bolts and nuts securing the generator to the bedplate. Also align the generator to the dowel pin holes and insert the dowels if installing the original generator.



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MEASURING DEFLECTION BETWEEN CRANK WEBS

Figure 2

1. DIAL INDICATOR
2. CRANKSHAFT WEB
3. CONNECTING ROD
4. CYLINDER LINER
5. PISTON

(g) Check the generator to crankshaft alignment by inserting a distortion gauge between the webs of the crankshaft at #1 cylinder crankpin. Be careful to place the gauge in a position as shown in Figure 2 with its axis parallel to the center

line of the crankshaft. Some of the later models have two punch marks on the crank webs to locate the distortion gauge. Spin the gauge a few times to make sure that it is seating properly. A change in the gauge reading after spinning indicates that it was not properly seated in the crank webs. After any error due to reseating has been removed, set the #1 crankpin at bottom dead center and the dial of the distortion gauge to zero.

(h) Rotate the shaft through one revolution and record the readings at the 4 quarter points. The difference between the top and bottom dead center positions should not exceed 0.003" for correct alignment and the opposite horizontal positions of the crank should not differ by more than 0.0015".

(i) If the difference between the top and bottom dead center positions is greater than 0.003", remove shims from under the generator mounting flange if the reading is *minus*, and add shims if the reading is *plus*, at the rate of approximately 0.001" distortion is equal to 0.005" change in shims under generator flange.

(j) After the generator has been correctly shimmed, a final check should be made with the distortion gauge. If the difference between the top and bottom dead center positions is within the allowed limit of 0.003" but the difference between the opposite horizontal positions of the crank is not within the allowed limit of 0.0015" move the outboard end of the generator in the direction in which the crank is pointing when the gauge reading is the least. This corrects the misalignment in a horizontal plane.

(k) When the generator alignment is correct, the generator mounting flanges should be doweled to the engine bedplate. The generator coupling bolts and flange mounting bolts should be tight when the final distortion check is made. If the

original generator is installed, steps (i) and (j) should not be necessary unless step (h) shows more than the allowed limits.

SPECIFICATIONS

CRANKSHAFT

	New	Limit
Main and thrust journal diameter.....	8.746" - 8.747"	
Crankpin journal diameter.....	8.371" - 8.372"	
Thrust bearing journal length.....	8.750" - 8.752"	
Out-of-roundness of journals and crankpins	0.0005"	0.0015"
Non-parallism of journals and crankpins..	0.0005"	
Squareness of flange face on a 15" diameter circle to center line of crankshaft...	0.001"	

MAIN BEARINGS

DESCRIPTION

These bearings are precision machined as full halves with crush included and do *not* require shims between the shells. As no shims are used, these shells are not adjustable to take up for wear and must be renewed when the shell is worn below the low limit of thickness, or the clearance between the shaft and the shell is beyond the recommended limit (see bearing specifications). Do not reject a shell just because it has worn through the plated surface in its bore as this is merely a "run in" surface to allow the bearing to better conform to the shaft.

The bearings consist of two shells held together with dowel pins, the lower shell resting in the bearing saddle. The upper shell is held in place by a bearing cap and a dowel that is recessed in both the shell and the cap. Each shell is stamped with its bearing number and the shells are so arranged that the numbers are all on the camshaft side of the engine and are visible from the pump end of the engine. The bearing caps are stamped with the bearing number on the shoulder of the cap and should be placed with the numbers on the camshaft side of the engine. The thrust bearing cap is stamped with a zero and the main bearings numbered from one to eight from the generator end. There are no shims under the caps or between the bearing shells as on older models.

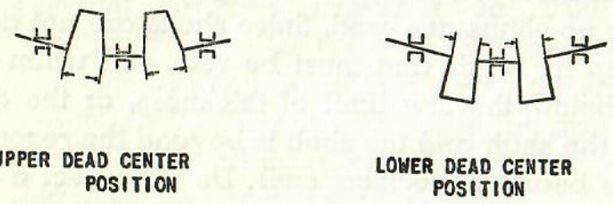
MAINTENANCE

1. Main Bearing Alignment

A method of checking the misalignment of the main bearings is by measuring the distortion of the crankshaft in one revolution of travel. It is suggested that the misalignment of all eight cranks be measured according to the procedure listed below and this data be used as a basis of comparison with subsequent checks to determine the presence of wear or deterioration of the bearings.

An increase in misalignment is only an indicator of an undesirable condition and further checking is necessary to determine its cause although it usually warrants the removal and inspection of the main bearings. The procedure is as follows:

(a) Remove the indicator cock or special plug, if this is the case, from the #1 cylinder head and con-



EFFECT OF MISALIGNMENT OF MAIN BEARING

STRAIN GAUGE READINGS								
CYLINDER NUMBER	1	2	3	4	5	6	7	8
A - CRANKPIN IN BOTTOM POSITION WITH AIR	0	0	0	0	0	0	0	0
B - CRANKPIN IN BOTTOM POSITION * AIR RELEASED								
C - CRANKPIN IN FRONT POSITION (CAMSHAFT SIDE)								
D - CRANKPIN IN TOP POSITION WITHOUT AIR								
E - CRANKPIN IN TOP POSITION WITH AIR								
F - CRANKPIN IN REAR POSITION (MANIFOLD SIDE)								
G - DIFFERENCE FRONT AND REAR (C MINUS F)								

D 1003

CHECKING ALIGNMENT OF MAIN BEARINGS

Figure 3

nect up a 100 p.s.i. air supply and pressure gauge.

(b) Loosen the valve tappets, remove the rocker arm stud nuts, and lift off the rocker arm assembly. This is to prevent the valves from opening during a complete revolution of the #1 crank. (For setting valve clearances when replacing rocker arm assembly see Section 7.)

(c) Bar the engine over until the #1 crank is in its bottom dead center position. A level protractor held against the crank webs will give a sufficiently accurate setting.

(d) Admit air to #1 cylinder and regulate the pressure to approximately 100 p.s.i. This will force the crankshaft to a firm seat in the bearings adjacent to the cylinder.

(e) Place the distortion gauge between the webs of #1 crank [see Page 105, Item (g)] and set dial to zero with air pressure in the cylinder. Install and read from manifold side of engine. This is reading "A" on chart.

(f) Release air pressure and record reading. A chart showing sample readings for the first and last cylinders is shown in Figure 3. This is reading "B" on chart.

(g) Bar engine over from camshaft side of engine until crank webs are parallel with top of bedplate which would be 90° of rotation from bottom dead center and record reading. This is reading "C" on chart.

(h) Bar engine over in same direction until crank is at top dead center. Check this with a level protractor. Record the reading which in this case is reading "D" on the chart.

(i) At this point it is advisable to block the crankshaft with two steel or wood blocks between the barring ring and the bedplate to prevent it from rotating when air pressure is applied to the cylinder. Make sure that the reading "D" is not changed in the process of blocking the shaft.

(j) Admit air to the cylinder (100 p.s.i.) and record the reading as shown on the chart as "E". Release the air pressure and unblock the crankshaft.

(k) Continue barring engine in same direction until crank webs are again parallel with the top of the bedplate but on the opposite side from step (f). Record the reading as shown on the chart as item "F".

(l) The difference between the top and bottom positions with air, measurement "E", should not be less than +0.001" and not more than +0.003". The difference between the front and rear positions should not be more than 0.0015"—see "G" on chart. As the engine bearings wear, the measurement "E" will increase and a set of readings for all eight cranks might show one or two readings in excess of 0.003". This dos not mean definitely that the bearings are bad but does warrant an inspection of the main bearings.

2. Main Bearing Removal

(a) Remove the lubricating oil supply line to the main bearing cap.

(b) Remove the top nuts of the four main bearing cap bolts and let the bolts drop back into the crankcase.

(c) Knock the cap loose with a lead hammer and lift out through the crankcase door. Remove the shell to cap dowel and the upper bearing shell.

(d) Bar the engine over until the oil hole in the bearing journal shows up and insert the main bearing removing tool (BLW Pt. No. 60-70-120). WARNING: Do not use any other tool or substitute as this will damage the bearing saddle and probably the shell and journal. Continue barring the engine over until the lower shell is rolled out. For the lower shell in the thrust bearing this procedure is varied by using the thrust bearing

removing dowel (BLW Pt. No. 600-70-140) and inserting it in the dowel hole in the crankshaft thrust collar. When removing more than one lower shell at a time, remove only every other one so that the crankshaft is never without proper support.

3. Inspection of Main Bearings

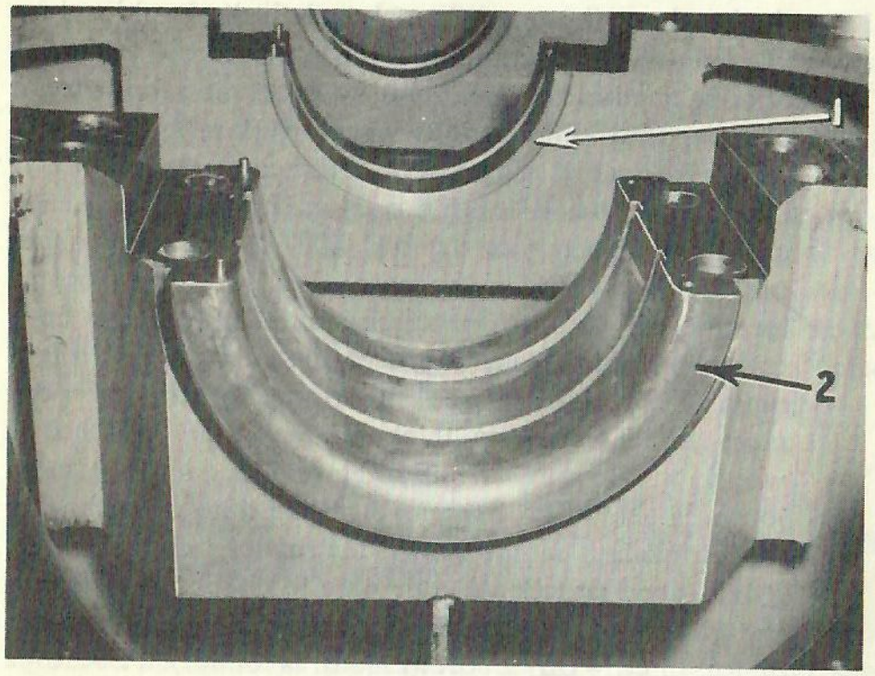
Examine each shell for cracks, pitting, or foreign particles embedded in the bearing metal. If there is any doubt about the condition of a shell, it should not be used again. With a micrometer measure the thickness of each shell at various points to determine the amount of wear and whether it is wearing evenly. If it is not wearing evenly, check the crankshaft distortion by the method listed in this section. If the distortion is greater than the permissible 0.003", check the chain and belt tensions on the crankshaft, and the generator and air compressor alignment. The specifications at the end of this section give the original and minimum shell thicknesses. A bearing shell that is worn close to its minimum thickness point or one that is wearing unevenly should be replaced. The main journals should be inspected at this time according to the crankshaft maintenance instructions on page 103. It is a good practice at this time to check the lubricating oil strainers and filters for the presence of bearing metal. In case any bearing metal is found, all bearings (Main, thrust, and crank) will have to be inspected and the oil passages and crankcase fllushed out. The above procedure should be followed if any bearing metal is found during routine filter and strainer cleanings. The frequency of main bearing inspection can be found on the maintenance schedule. When making a sampling inspection of main bearings the condition of the center main bearing will usually indicate the condition of the other main bearings.

4. Replacement of Main Bearings

(a) Roll in the lower shells by hand if possible and only resort to using the bearing removing tool when necessary.

(b) Replace the original bearing shells that are still usable on the same journals from which they originally came and in the same position. Do not put shells in backwards, see page 107 for details. Lubricate journals before replacing shells.

(c) Replace the shell to cap dowels and the bearing caps. Use a lead hammer to force the cap down tight but be careful not to cock it in doing so.



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MAIN BEARING

Figure 4

1. MAIN BEARING SHELL
2. THRUST BEARING SHELL

(d) Replace the nuts on the main bearing cap bolts and draw them up so that the cap is tightened down evenly. The nuts should be given a final tightening with a torque wrench to 500 ft.-lbs. (BLW Pt. No. for complete torque wrench set is 600-70-017.) The right and left hand wrench Pt. Nos. are 600-70-015 and 600-70-014 respectively.

(e) Install the lubricating oil supply lines to the bearing caps.

(f) Check the bearing clearances by inserting long bearing feelers between the crankshaft and the top of the shell at both ends of the bearing. The clearances will be equal to the thickness of the largest feeler that can be easily inserted plus 0.001". The bearing cap bolts must be drawn up tight when measuring bearing clearances. The clearances are listed in the specification for this section.

(g) Sometimes it is not possible to get a feeler gauge between the crankshaft and the shell on the thrust bearing. In this case the bearing clearance should be measured by "taking leads" as described below.

1. Remove the thrust bearing cap and shell as described in (a) through (c).
2. Twist together two strands of 1/64" diameter soft lead wire (or 1 ampere fuse wire) and place across the shaft journal approximately 2" from each end of the shell.
3. Without disturbing the wires, reassemble the shell, dowel, cap, and tighten up the bolts to 500 ft. lbs.
4. Remove the cap and shell and measure the thickness of the mashed wires with a micrometer. This measurement is the actual clearance between the shell and the journal in the thrust bearing.

(h) Check the main bearing alignment according to the method outlined on pages 108, 109 and 110 for all eight cranks. The distortion for any crank should not exceed 0.003".

As outlined above the bearing clearances should all be within the specified limits and the distortion less than 0.003" before an engine is run

after a bearing overhaul. The lubricating oil pressure should be closely watched when an engine is run after an overhaul.

SPECIFICATIONS

MAIN BEARINGS (GRIDDED)

	New	Limit
Main and thrust bearing running clearance	0.010" - 0.014"	0.018"
Main and thrust bearing shell thickness	0.6205" - 0.6215"	0.616"
Thrust bearing end clearance	0.016" - 0.022"	0.035"
Thrust bearing shell length (outside)	8.730" - 8.734"	
Thrust bearing shell length (inside)	7.000" - 7.004"	
Main and thrust bearing shell outside diameter (free state)	10.002" - 10.007"	
Main and thrust bearing shell split line height	5.002" - 5.003"	

MAIN BEARINGS (TRI-METAL)

	New	Limit
Main and thrust bearing running clearance	0.006" - 0.010"	0.014"
Main and thrust bearing shell thickness	0.6225" - 0.6235"	0.618"
Thrust bearing end clearance	0.008" - 0.014"	0.030"
Thrust bearing shell length (outside)	8.738" - 8.742"	
Thrust bearing shell length (inside)	7.000" - 7.004"	
Main and thrust bearing shell outside diameter (free state)	9.9995" - 10.000"	
Main and thrust bearing shell split line height	5.002" - 5.003"	

FRAME

The frame is a welded structure forming the upper part of the crankcase and the water jacket chamber. Bored seats provide for supporting the cylinder liner. The water header is welded integral with the frame. A camshaft housing is welded to the side of the frame. Openings are provided for access to the crankcase and crankshaft bearings. Oil-tight covers close these openings. The frame is bolted to the bedplate along the outside flange and by four bolts at each main bearing.

MAINTENANCE

At any time that liners are removed from the block, the water jackets should be thoroughly cleaned of scale and rust. Inspect the top liner seat of the block for any evidence of cracks resulting from head pressure on the liner. Any pitting marks or rough spots on liner seats of the block should be reconditioned as outlined in liner section of this book. Also check the cylinder head studs for evidence of cracks.

CYLINDER LINER

The cylinder liners are made of alloy cast iron and are fitted into the upper section of the frame. A copper gasket at the top and rubber rings at the bottom seal the liner in the frame to form a water jacket. The liner bores are treated to reduce wear and lengthen the life of the liner.

MAINTENANCE

A liner should not be removed except for replacement or when cleaning of water jacket or reconditioning of liner seating joint in frame is required.

Before removing a liner, mark top of liner and frame so that liner may be reassembled correctly. Drain water from frame jacket and rig up a trough of canvas or heavy paper inside of crankcase to catch any dirt that may fall when removing liner.

After liner is removed from frame, clean the outside of liner of scale and dirt deposits, also clean water jacket space in frame. If liner seat in frame shows any pitting marks or rough spots, it should be reconditioned by scraping and coarse lapping as required.

After checking seat in frame, liner with gaskets may be installed. Both sides of gasket are to be coated with white lead and oil. Never re-use old copper or rubber gaskets.

After liner is in place, determine the bore in planes parallel to and right angle to centerline of crankshaft. The out of roundness should not exceed limits as specified at end of this section. The water passages in the frame should be subjected to a hydrostatic test at a pressure of 60 p.s.i. after replacing any liners.

SPECIFICATIONS

LINER BORE	NEW	LIMIT
Diameter	12.750" - 12.752"	12.792"
Out of round	Not more than .0015"	.004"
Taper	Not more than .002" (in length of liner)	.004"

PISTON AND CONNECTING ROD

The pistons are aluminum alloy castings with a steel tube cooling coil cast into the top. Four compression rings and one oil scraper ring are used above the piston pin and two oil scraper rings below the piston pin.

The piston pin is of the full floating type. Plugs fitted into the piston retain the pins in position.

The connecting rod is a drop forging, drilled its length for piston pin lubrication and piston cooling oil. The connecting rod cap is a steel forging bolted to the rod with four bolts. Crank pin bearings are precision made steel shells lined with lead content metal. Piston pin bearings are a solid bronze bushing pressed into the eye end of connecting rod.

MAINTENANCE

After removing cylinder heads but before removing pistons, clean upper end of liner bore if carbon deposits are excessive. Cover top of piston to prevent any carbon or grinding from entering between piston and liner.

Bar piston to top position of stroke and remove connecting rod bolts. Insert eye bolts in tapped holes in piston top, attach hoist and pull piston and rod assembly. When hoisting piston, care must be exercised to prevent end of rod from touching and scratching liner bore.

Set each piston with rod on blocks preferably in a vertical position. Care should be taken to keep all parts for each piston and rod assembly together to facilitate reassembly.

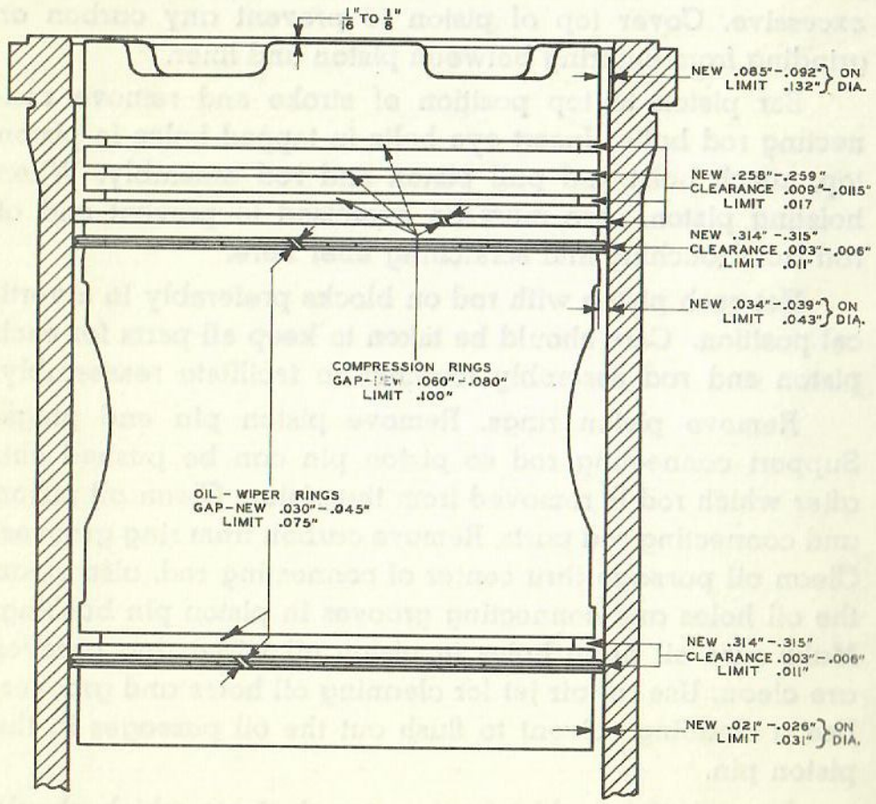
Remove piston rings. Remove piston pin end plugs. Support connecting rod so piston pin can be pushed out, after which rod is removed from the piston. Clean all piston and connecting rod parts. Remove carbon from ring grooves. Clean oil passage thru center of connecting rod, also clean the oil holes and connecting grooves in piston pin bushing. Make sure oil drain holes in piston oil wiper ring grooves are clean. Use an air jet for cleaning oil holes and grooves. Use a cleaning solvent to flush out the oil passages in the piston pin.

Inspect piston skirt for any rough spots which should be removed by using fine emery cloth and oil. Be sure to wash off all grit after using emery. Piston diameter should

be checked and clearances in liner at top and bottom. Check clearance of rings in grooves and if not within limits specified, the grooves should be refinished and oversize width rings installed. The end gap clearance should be checked when ring is inserted in a true horizontal plane in cylinder near the bottom. The clearances to be adhered to are listed at end of this section.

Inspect piston pins and bushings for wear. The clearance for pin in bushing should be not less than .005" or more than .008" on diameter. Check also clearance of pin in bores of piston. This clearance should not exceed .002".

The plugs are fitted into the piston counter-bores with an interference fit of 0.002" to 0.0035". Plugs should be placed in a can of dry ice for approximately ½ hour prior to insertion into piston counter-bores. After insertion, plugs should be held against shoulder of counter-bore, until plugs are tight. Do not file outside diameter of plugs to facilitate application to piston.



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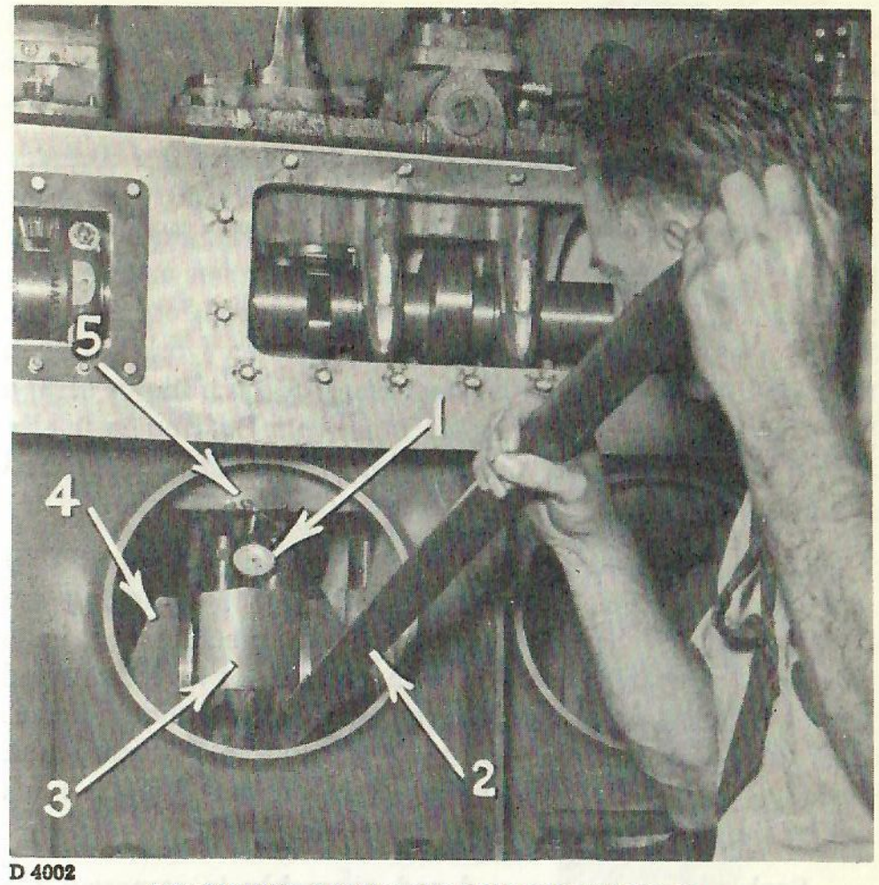
PISTON AND PISTON RING CLEARANCES
Figure 1



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MEASURING CRANK PIN BEARING CLEARANCE
Figure 2

1. DIAL INDICATOR
2. PRY BAR
3. CONNECTING ROD
4. CRANKSHAFT
5. CYLINDER LINER

The crank pin bearings should be carefully inspected. If any rough spots or scratches are found on crank pin, they should be reconditioned with a fine oil stone. Do not use file or emery cloth. The crank pin bearing clearance should be checked when the rod and piston are assembled in the engine and the connecting rod bolts are drawn up tight. Locate crank pin in top position and pry or jar rod and piston up and down with a bar of suitable length. See Fig. 2. Measure with a dial gauge the up and down movement of the rod relative to the top of one of the crank webs. The movement of the rod as indicated on the dial gauge is the actual crank pin bearing clearance. The clearances are listed at end of this section.

If new shells are to be installed, a careful inspection should be made that the shells fit properly into the connecting rod foot and cap, also that the bearing has the proper clearance.

Push the top and bottom shells firmly into the connecting rod foot and cap, using a wooden block and two screw clamps. The block should be shaped to conform to the inside of shells. The two joint faces should then extend from .001" to .002" outside the joint faces of the rod foot and cap. The shells are precision made and any fitting work to obtain this condition should not be necessary. Do not file or scrape joint faces of shells. When the crank pin bearing is finally assembled the two shells will be forced to a firm seat around the entire peripheral area when the bolts are drawn up.

Connecting rod bolts should be carefully inspected. If any defects, such as cracks or evidence of stretching are revealed, bolts should be replaced. Connecting rod bolts which are known to have been abused or overtightened must be replaced. In the event a piston seizure should occur, it is advisable to replace all the rod bolts in that particular cylinder. Filing or grinding of connecting rod bolts must not be permitted under any circumstances.

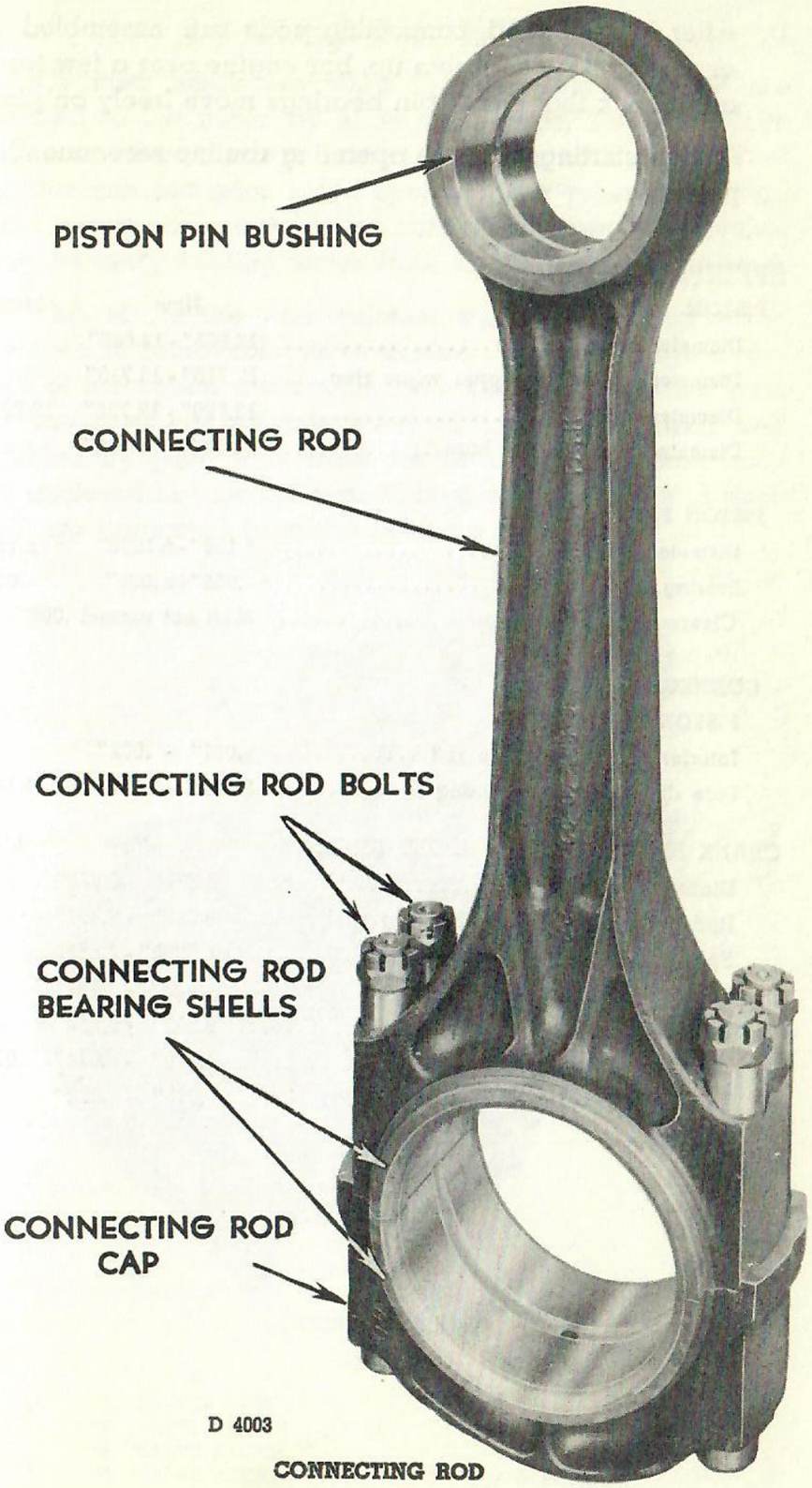
Each time a piston and rod assembly is removed the liner should be inspected and measured. (See liner instructions.)

When reassembling the piston and connecting rod in the engine, the following routine should be followed.

A. All wearing surfaces of piston, liner, piston pins, crank pins and bearings should be covered liberally with new lubricating oil.

B. Connecting rod bolts should be reassembled in the same place as originally located. Bolts, nuts and connecting rods are marked for ease of reassembly.

C. Tighten bolts evenly, drawing up on each bolt only a fraction of a turn each time. Do not sledge. When drawn up properly the total stretch of each bolt should be .009"-.010" measured from end to end of bolt. Measurements must be taken before and after tightening at exactly the same points and as close as possible to the center of the bolt.



CONNECTING ROD
Figure 3

D. After pistons and connecting rods are assembled in engine and bolts drawn up, bar engine over a few turns and check that crank pin bearings move freely on pins.

When starting, observe operating routine recommended on page 10.

SPECIFICATIONS

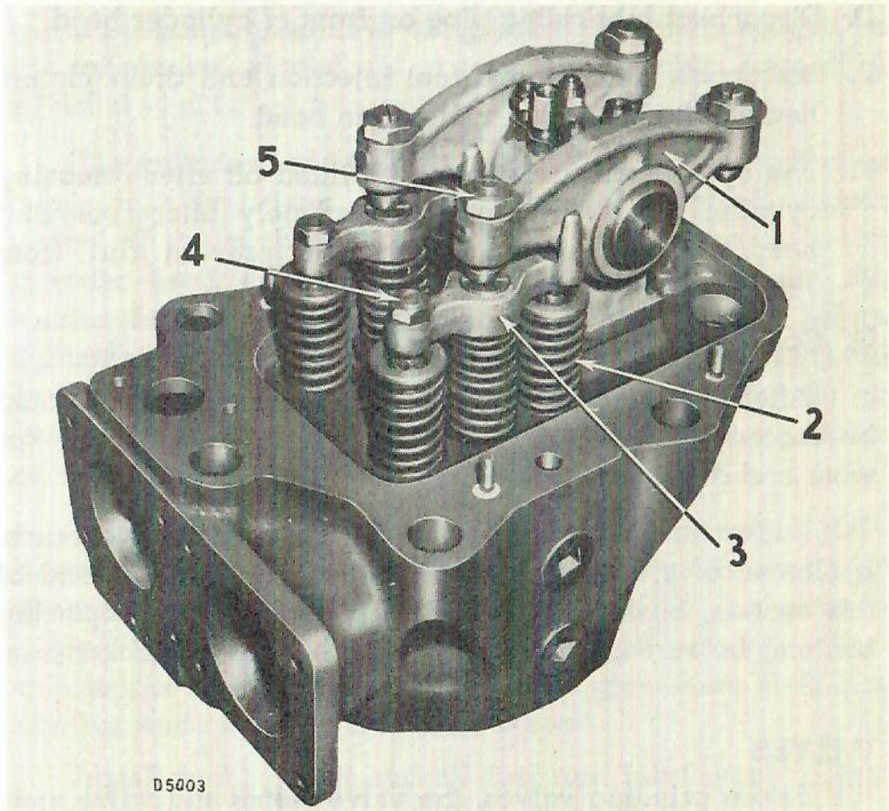
PISTON	NEW	LIMIT
Diameter at top	12.665" - 12.660"	
Diameter just below upper wiper ring	12.716" - 12.713"	
Diameter at bottom	12.729" - 12.726"	12.720"
Diameter of piston pin bore	5.1245" - 5.125"	
PISTON PIN		
Diameter	5.123" - 5.1235"	5.120'
Bearing Clearance	.005" to .008"	.010"
Clearance of pin in piston	Must not exceed .002"	
CONNECTING ROD		
PISTON PIN BUSHING		
Interference, bushing to rod	.001" - .002"	
Bore diameter after pressing in rod	5.1295" - 5.1305"	5.134"

CRANK PIN BEARING (GRIDDED SHELL)	*New*	*Limit*
Diameter crank pin	8.371" - 8.372"	...
Rod bore for crank pin bearing shell	9.250" - 9.251"	...
Split line height of shell	4.6265" - 4.627"	...
Bearing shell thickness	.433" - .434"	...
Outside diameter bearing shell	9.253" - 9.258"	...
Clearance bearing to crank pin	.010" - .014"	.018"
Clearance bearing to crank-lateral	.015" - .022"	...

CYLINDER HEAD

Cylinder heads are made of alloy cast iron and are attached to the frame by alloy steel studs. Two air intake and two exhaust valves are provided in each head. Fuel injector and indicator valve openings are provided. Aluminum covers enclose the valve gear mechanism. Removable jumpers carry cooling water from the frame into the head.

The air intake and exhaust valves are alloy steel, mounted in removable valve guides. A valve bridge under each of two rocker arms actuate the valves. The rocker arms are mounted on brackets attached to cylinder head and actuated by push rods from the camshaft. The push rods are enclosed in pipe casings. Valves, rocker arms and push rods are lubricated from the pressure system.



CYLINDER HEAD

Figure 1

1. ROCKER ARM
2. VALVE SPRING
3. VALVE BRIDGE
4. VALVE BRIDGE ADJUSTING SCREW & LOCK-NUT
5. TAPPET ADJUSTING SCREW & LOCK-NUT

MAINTENANCE

The following procedure should be followed in removing cylinder heads.

A. Remove both aluminum covers from cylinder head.

B. Drain water from engine. Remove all water connections. Remove exhaust header and air intake header bolts.

C. Remove rocker arms and supporting bracket from cylinder head as a unit. Push rods can then be lifted out thru the openings in cylinder head. Remove push rod casings by removing bottom and top flange bolts. Flanges can then be slipped up and down on tube so that tube can be lifted slightly and pulled out at the bottom.

D. Disconnect lubricating pipe on front of cylinder head.

E. Disconnect and remove fuel injection and drain piping. Remove fuel injection valve from head.

F. The cylinder head can now be lifted off after removing cylinder head stud nuts. Immediately after removing head, cover cylinder opening to prevent dirt from entering.

G. Completely dismantle rocker arms and valves.

After all parts are completely disassembled they should be thoroughly cleaned. All parts should be checked for wear and defects.

Rocker arm bearings should be checked for clearance. If clearance is not within specifications as listed at end of this section, bushings should be replaced. When replacing bushing be sure oil holes line up with holes in rocker arm.

VALVES

Before grinding valves, the valve stems and valve stem guides should be inspected for scoring or excessive clearance. If replacement of guides is deemed necessary this should be done ***before*** valve grinding. Slight scoring of valve stems can be stoned smooth. Inspection of valves and valve seats will determine whether valve seat grinding is necessary.

Improper seating or excessive wear should be corrected by grinding. If the seats on the exhaust valve and cylinder head show pitting marks, these should not be removed by grinding. Such pitting marks may appear after a relatively short operating period, but usually will not develop further after prolonged operation. Valve seats which show excessive wear should be reconditioned with a valve seat grinder.

Inspect valve springs for defects such as fine cracks or reduced free length. Spring must not show any set after being compressed with coils touching. Free length should be as specified at end of this section.

When reassembling valves in cylinder head, care should be taken not to interchange exhaust and intake valves. Cover valve stems with new lubricating oil when inserting in valve guide bushings. Height of valve springs in place should be 4½ inches and slotted nut at top of valve stem should be adjusted to obtain this height. Lock nut with split pin.

The cylinder head to liner gasket face should be free of burrs or indentations. Use a new soft annealed copper gasket of the proper thickness. Use new gasket between cylinder head and exhaust header. Partially tighten the header bolts to align cylinder head and header before tightening cylinder head nuts. The cylinder head nuts should be tightened a fraction of a turn at a time, drawing up on every second nut in rotation so as to tighten head down evenly. Complete tightening of header bolts.

Reassemble push rod tube casings and insert push rods. Assemble rocker arms to cylinder head. Adjust valve tappet clearance as outlined in paragraphs "A" to "E" inclusive of Engine Timing Section. Each valve bridge has one adjustable tappet screw. This must be set to give same clearance as other end of bridge with solid tappet.

Install fuel injector and all fuel and lubricating piping.

Cover all valve gear with a liberal supply of lubricating oil.

SPECIFICATIONS

VALVE BUSHINGS	NEW	LIMIT
Inside diameter	.875" - .876"	
Bushing to head—interference	.0005" - .0015"	

VALVES	NEW	LIMIT
Diameter of stem	.868" - .867"	
Clearance—stem to bushing	.007" - .009"	.013"
Valve seat angle	45°	
Diameter of head	4 3/16"	
Lift	.938"	

VALVE SPRINGS	
Free length	5 1/4"
Length—valve closed	4 1/2" - 131 lbs.
Length—valve open	3 9/16" - 295 lbs.

VALVE BRIDGE SPRING	
Free length	5 1/4"
Length—valves closed	4 3/8" - 153 lbs.
Length—valves open	3 7/16" - 317 lbs.

ROCKER ARM		
Bushing to rocker arm—interference	.001" - .004"	
Inside diameter of bushing—after pressing in rocker arm	2.998" - 2.999"	
Diameter of shaft	2.996" - 2.995"	
Clearance—bushing to shaft	.002" - .004"	.006"

VALVE AND CYLINDER HEAD GRINDING SPECIFICATIONS	NEW	LIMIT
Thickness of valve head at outer edge	3/32"	3/64"
Depth of seat in cylinder head	5/16"	9/16" *
Width of valve seat	1/4"	

*Using a new valve. Limit is 33/64" using a remachined valve.

CAMSHAFT AND CAMSHAFT DRIVE

The camshaft is an alloy steel forging made in two pieces, flanged and bolted together at the center. The cams are forged integral with the shaft and are hardened and ground to shape. The camshaft is supported in precision type bearing shells mounted in the fuel pump supporting bracket. A thrust bearing is provided for the camshaft at the generator end of engine. The camshaft is hollow drilled for lubricating oil supply to its bearings.

The camshaft is driven by means of a roller chain and sprockets from the crankshaft at generator end of engine. An idler sprocket is used for maintaining chain tension. Lubrication is provided by a pressure spray nozzle directed at the chain.

MAINTENANCE

The camshaft bearings should be checked for clearance with a feeler gauge. Also check thrust bearing clearance.

A camshaft bearing may be replaced by removing bearing cap and lower shell and rotating upper shell around shaft. New bearing shells are applied in the reverse order. Since the camshaft bearings are readily accessible, it should not be necessary to remove the camshaft except if its condition requires replacement.

If either or both halves of the camshaft require removal, the following procedure is necessary.

A. Remove chain drive housing, chain and camshaft sprocket. Also remove camshaft thrust bearing bracket.

B. Remove cylinder head top cover, rocker arms and bracket, push rods and push rod casing.

C. Remove governor and overspeed stop.

D. Support camshaft on wood blocks resting on bottom of camshaft trough and remove bearing caps and shells. Remove camshaft follower brackets.

E. Disconnect camshaft joint at center of engine. Either half of camshaft can be moved toward ends of engine and coupling end of camshaft lifted out thru front opening of camshaft casing.

CHAIN DRIVE

The camshaft chain drive should be inspected periodically for wear and tension adjustment. In order to check the tension, remove inspection opening cover plate on chain casing and apply strong hand pressure to center of longest chain span. The total movement or slack should be approximately ¾".

Chain tension is adjusted by the idler sprocket. After loosening the lock nut the idler bracket pin can be turned until the chain slack is taken up. Tighten the lock nut and recheck tension. Repeat if necessary until chain is properly adjusted. The lock nut must be drawn up tight after final adjustment is made.

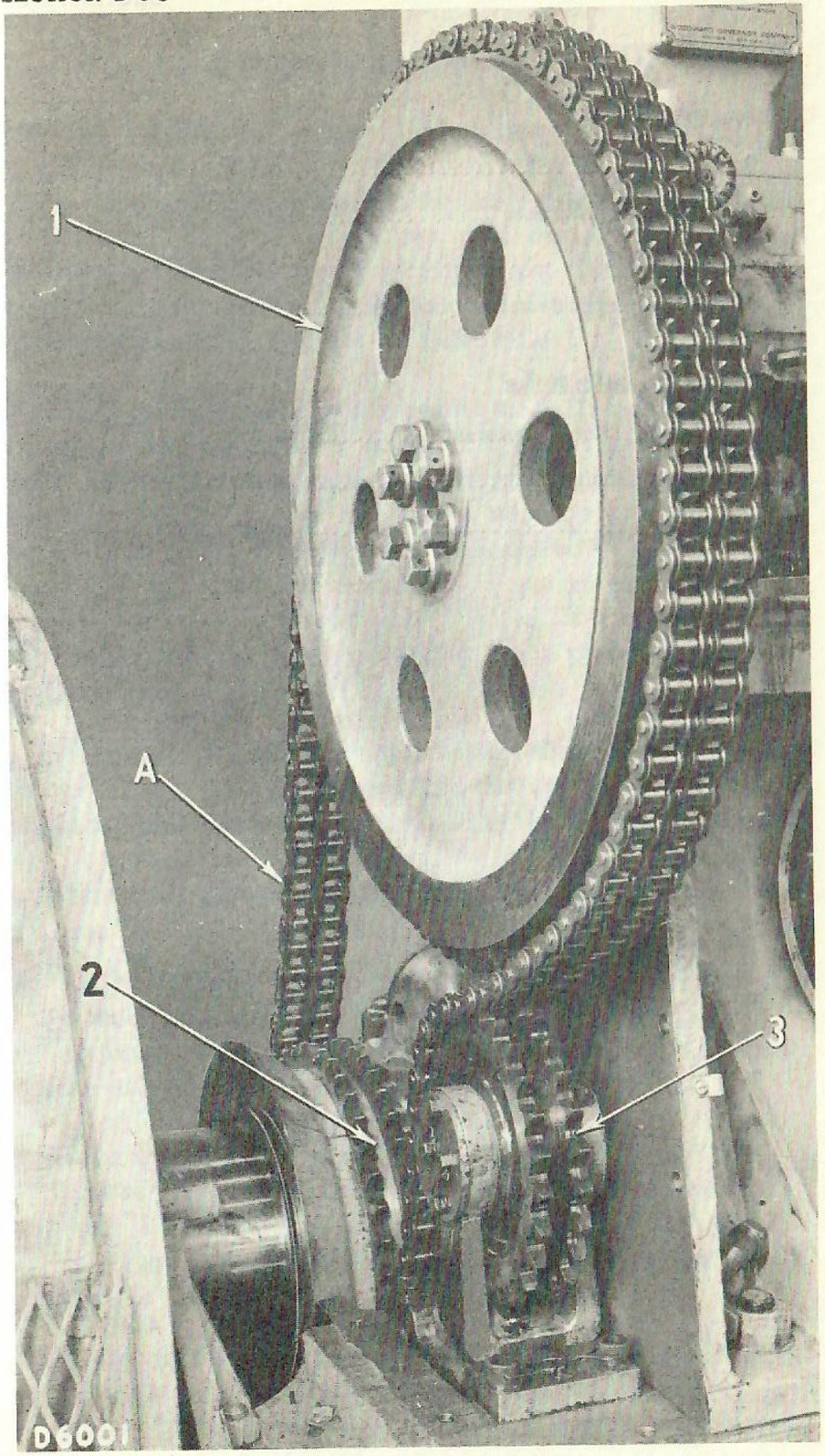
After chain tension has been readjusted, the engine should be barred at least two revolutions in direction of normal rotation to make sure that tension is not greater than desired at any position of sprockets.

After the full range of idler sprocket adjustment has been utilized a new chain should be installed. Do not use an offset or half link in the chain.

When a new chain is installed, it should be installed with no movement or slack at point "A". This allows for initial stretch during the first few days of operation. The tension in a new chain must be checked after approximately 150 hours operation, and the chain adjusted as required. This also applies to the chain in a new engine.

The chain furnished with the engine has a removable link. The link side plate should fit very tightly on the pins. It is necessary when assembling the link to drive the side plate in place by using a heavy steel plate. The side plate is secured in place by means of a heavy lockwire which must be secured by crimping. After the lockwire is in place, tap lightly on ends of link pins in order to obtain proper clearance for end plate.

Lubrication of the chain should be checked whenever the inspection cover on chain casing is removed. It is advisable to check the engine timing as described in the next section after making any adjustments to the chain.



CAMSHAFT CHAIN DRIVE
Figure 1

1. CAMSHAFT SPROCKET
2. CRANKSHAFT SPROCKET
3. ADJUSTABLE IDLER SPROCKET

SPECIFICATIONS

CAMSHAFT	New	Limit
Journal diameter	3.4955" - 3.4965"	
Bearing shell thickness	.0855" - .0860"	
Bearing clearance	.003" - .006"	.010"
Thrust bearing clearance—(lateral)	.006" - .010"	.025"

CAMSHAFT DRIVE IDLER	
Bushing to idler—interference	.002" - .004"
Diameter of shaft	1.999" - 1.998"
Clearance	.004" - .006"

ENGINE TIMING

For intervals at which the engine timing should be checked consult your maintenance charts. The camshaft drive chain will increase slightly in length due to stretch and wear. Therefore the timing must be adjusted to compensate for the increased length in the chain. In a new engine or after a new chain has been installed the timing should be checked after about 10,000 miles.

The cams for all cylinders are made integral with the camshaft and located in exact positions relative to each other. Therefore it is only necessary to inspect and adjust the opening position of one valve, say the exhaust valves on No. 1 cylinder. However, the exhaust valve tappet clearance for No. 1 cylinder should be set according to the method outlined in paragraphs "A" to "E" following. The injection pump timing requires that each pump be checked and adjusted.

Before inspecting and adjusting the timing it is important to check, and correct if necessary, the camshaft drive chain tension. This operation is described in the preceding section.

The timing of valves may be inspected and adjusted as follows.

A. Bar the engine over so that the valve being inspected is closed (cam roller on low portion of the cam). The piston must be on the expansion stroke when inspecting the exhaust valve opening position.

B. With a feeler gauge of correct thickness as specified at end of this section, check the valve tappet clearance "1" and "2" under each end of valve actuating bridge "3." See Fig. 1. The clearance should be 0.025" at points "1" and "2"

C. If the above checking indicates an adjustment is necessary, loosen lock nut and back out adustable tappet screw "4" in one end of bridge approximately ⅛ inch. Opposite end of bridge has solid non-adjustable tappet pin "5."

D. Adjust screw "6" up or down to obtain correct clearance between valve stem and solid tappet pin "5" on bridge. Do not change screw "7" as long as lockplate is securely crimped in place.

E. The adjustable tappet screw "4" in bridge should then be adjusted to give same clearance between valve stem as opposite end of bridge. Lock tappet screw.

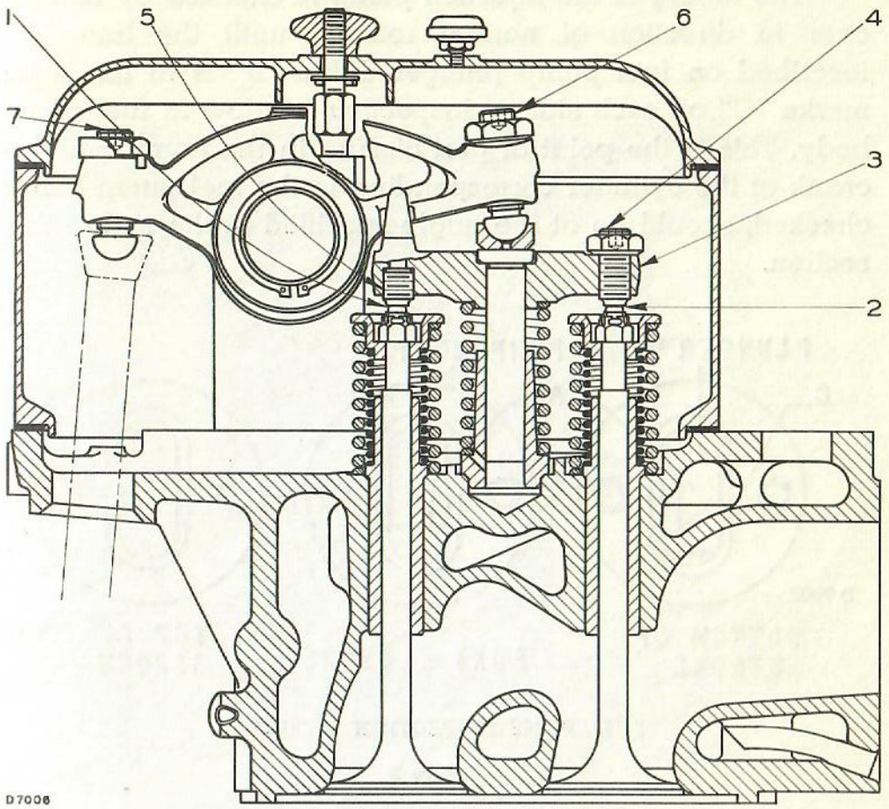
F. Bar engine over slowly in direction of normal rotation until valve bridge pressure pins touch the valve stems. This is the actual opening position of the valve.

G. Ascertain by means of a level protractor on side of crank cheek whether or not the timing of the valve is correct. The timing should not be more than one degree earlier or one degree later than specified. If the bedplate is not level, the protractor reading should be corrected accordingly.

H. In the event the valve timing is not within proper limits, it may be corrected by changing the angular relation between the camshaft and the camshaft chain sprocket. Bar engine over to the position at which the valve should begin to open. Block the crankshaft in this position. Remove the lockwire and loosen camshaft sprocket bolts sufficiently to permit angular movement of the camshaft with respect to the sprocket.

If the timing is to be advanced, turn the camshaft in the same direction as normal rotation of engine until bridge tappets just touch valve stems. In the event the timing is to be retarded, the camshaft is turned in the opposite direction until bridge tappets are clear of valve stems and then turned the same direction as for late timing until touching.

I. After adjustment is made, retighten sprocket bolts. Bar engine over thru one cycle or two revolutions in direction of normal rotation and recheck the timing of same valve.



VALVE TAPPET ADJUSTMENT

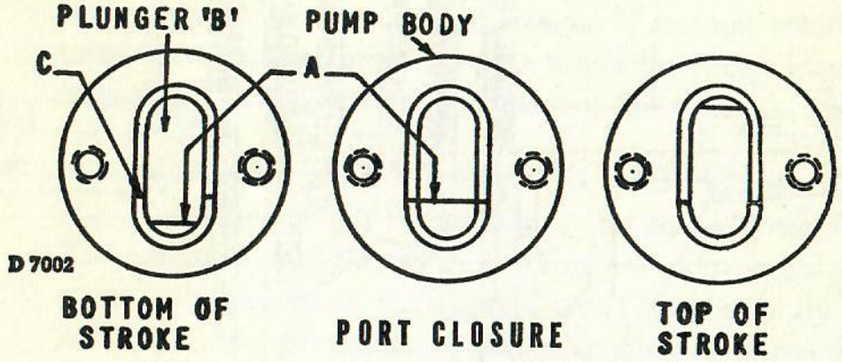
Figure 1

J. If the timing of valves is satisfactory install the camshaft sprocket bolt lockwire.

FUEL INJECTION PUMP TIMING

The fuel injection pump timing will be affected by any stretch or wear in the camshaft drive chain, similar to the inlet and exhaust valves. If when checking valve timing, the angular relation between the camshaft and camshaft sprocket is altered, the fuel injection pump timing must be checked and corrected if necessary. The pump for each cylinder must be checked. A replacement of a pump plunger and cylinder or a complete pump will require checking the timing on that particular cylinder.

The timing of the injection pump is checked by barring over in direction of normal rotation until the line "A" inscribed on fuel pump plunger guide "B" is in line with marks "C" on each side of inspection window in fuel pump body. This is the point of port closure in the pump and the crank of the cylinder corresponding to the fuel pump being checked, should be at the angle specified at the end of this section.

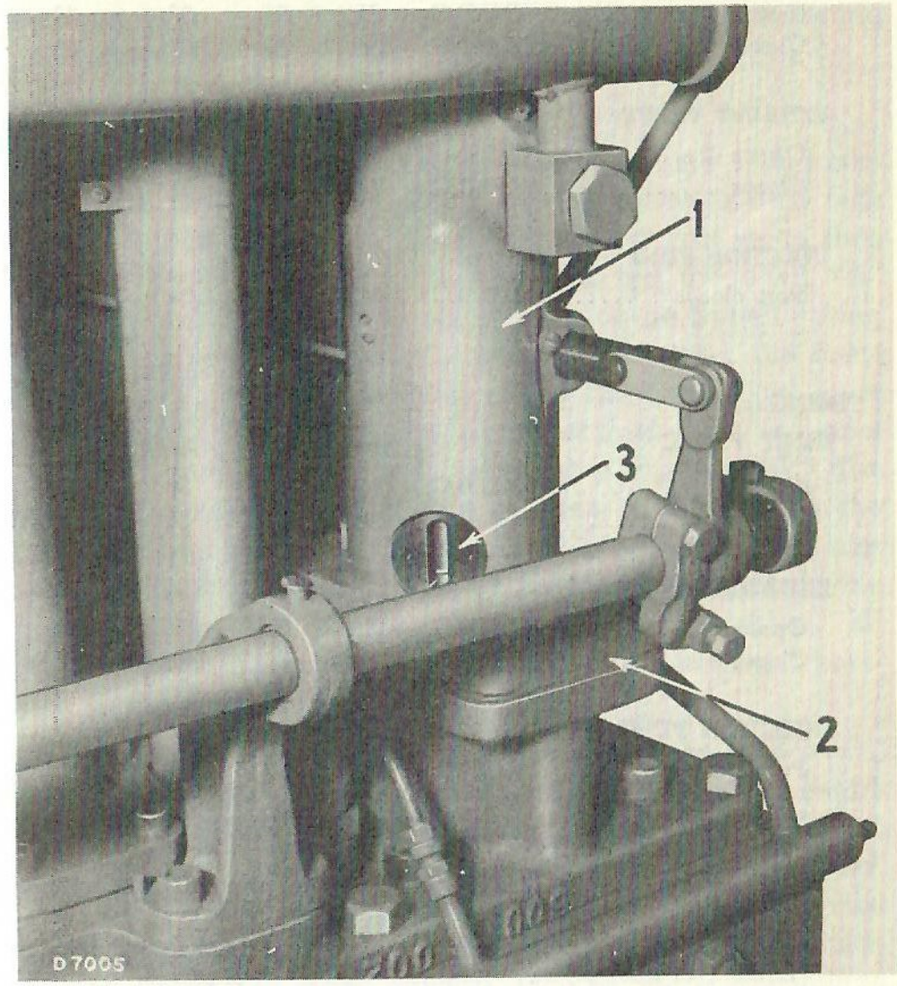


FUEL PUMP INSPECTION WINDOW

Figure 2

If the angle is not as specified, it can be corrected by adding or removing shims under the fuel injection pump body. This raises or lowers the position of pump cylinder in relation to the plunger and thus alters the beginning of actual injection for the individual pump. Adding shims retards injection and removing shims advances injection. Approximately .015" shim thickness corresponds to 1° on the crankshaft. The mark "A" in all pumps should be visible through the window port in pump body for both top and bottom of plunger travel.

When a complete new pump, or plunger and cylinder assembly is to be installed, first bar engine over slowly until mark "A" on the pump on which the replacement is to be made, aligns exactly with the marks "C" on window port of pump body. Make replacements without changing position of camshaft. After new parts have been installed, the mark "A" should align exactly with marks "C." If not, change the thickness of shims under fuel pump body as required.



FUEL PUMP

Figure 3

1. FUEL INJECTION PUMP
2. SHIMS FOR TIMING
3. TIMING MARKS

SPECIFICATIONS

TIMING		Hesselmann Pistons*			
		Supercharged			Normally
INLET VALVE		4-Pipe‡	3-Pipe‡	2-Pipe‡	Aspirated
Opens	°B.U.D.C.	81	81	83	32
Closes	°A.L.D.C.	39	39	37	48
EXHAUST VALVE					
Opens	°B.L.D.C.	56	56	47	52
Closes	°A.U.D.C.	79	79	65	28
INJECTION PUMP					
Port closes	°B.U.D.C.	21	24	24	31

TIMING		Saucer-Shaped Pistons†			
		Supercharged			Normally
INLET VALVE		4-Pipe‡	3-Pipe‡	2-Pipe‡	Aspirated
Opens	°B.U.D.C.	86	86	86	32
Closes	°A.L.D.C.	34	34	34	48
EXHAUST VALVE					
Opens	°B.L.D.C.	61	61	50	52
Closes	°A.U.D.C.	74	74	62	28
INJECTION PUMP					
Port Closes	°B.U.D.C.	26	29	29	31

*This type of piston has a depressed center portion but with a raised cone in the center of this depression.

†This type of piston has a concave depression in the center of the piston.

‡The types of turbochargers are most easily identified by the number of inlet pipes.

(Tolerance on all above ratings—± 1° of crank angle)

VALVE TAPPET CLEARANCES (Cold engine at 70° F.)

Exhaust valves	.027"-.029"
Intake valves	.006"-.008"

VALVE TAPPET CLEARANCES (Hot engine at 135° F.)

Exhaust valves	.033"
Intake valves	.013"

For timing purposes only, the tappet clearance should be set at .025"

The above temperatures apply to the water temperature with the engine shut down.

GOVERNOR

The governor is of the Woodward Hydraulic relay type and is driven from the camshaft by a set of bevel gears. Its function is to control the speed of the engine at a setting determined by the throttle position in the cab.

OPERATION OF GOVERNOR

The shaft "A" which is connected to engine speed control in the cab carries a gear "B" which engages a gear rack on the flyball seat "C." The speed of the engine is thus changed by the throttle in the cab turning the shaft "A" which in turn changes the compression of the flyball spring "D." When engine is running at a steady speed, the force exerted by this spring is balanced by the centrifugal force of flyballs "E" and then the center shoulder on the pilot valve "F" covers the ports in pilot valve bushing "G." The gear at the bottom end of this bushing, together with the gear "H" (not shown) form a pump which supplies oil under pressure to the pilot valve and also to the top side of the power piston "J." The spring loaded piston valve "K" relieves the excess oil and thus maintains a constant pressure in the system.

When the load on the engine increases, the engine will slow down momentarily thus reducing the speed and centrifugal force of the governor flyballs. The spring will then force the guide rod "L" and the pilot valves "F" downward. This will uncover the ports in pilot valve bushing "G" thus admitting oil under pressure to the bottom of the power piston "J" and cause it to move upward. This motion is transmitted through link "M" and lever "N" to the terminal shaft, which latter is connected by means of a linkage to the engine fuel injection pump control shaft. When the load increases, the governor will increase the fuel discharge from injection pumps in order to maintain the engine speed.

When the load on the engine decreases, the engine will speed up momentarily thus increasing the speed and centrifugal force of governor flyballs. This will cause the spring to compress and also to move the pilot valve "F" upward. As the ports in bushing "G" are uncovered, the oil under the power piston "J" is permitted to drain out, and the oil pressure which is always maintained on top side of this

piston will force it downward in direction of reduced fuel discharge from the injection pumps.

In order to keep the governor from hunting, a compensating dashpot system is used. The actuating piston "P" of the dashpot is connected to the terminal shaft "O" through lever "Q" and links "R" and "S." This piston, therefore follows exactly each movement of the power piston "J." The receiving side of the dashpot contains a plunger "T" and a spring to keep the plunger in proper position. An oil passage connects the two dashpot chambers.

Referring to the first case of an engine load increase, the pilot valve moves downward and the power piston upward. By following through the motion of the levers and the terminal shaft, the actuating dashpot piston will move downward, pushing the plunger in receiving side of dashpot upward, which restores pilot valve to center and stops the power piston at the required new position. It is now necessary to keep the pilot valve centered until the engine speed picks up and the flyballs are vertical again. To accomplish this, the needle valve "U" under the receiving dashpot is adjusted in a position which will permit the oil to leak out and the plunger to return to center at the same rate the flyballs return to vertical position. Thus the pilot valve and all other parts except the power piston and dashpot actuating plunger will have returned to original positions.

The compensation adjustments as originally set may not be satisfactory after the engine has been put in operation. Although the governor may appear to perform satisfactorily, it is advisable to check compensation adjustment as follows:

A. Loosen the nut holding the compensation adjusting pointer "V" and set the pointer at its extreme downward position. This moves the lever "W" toward the front of governor and reduces the stroke of dashpot piston "P" relative to the stroke of the power piston "J."

B. Remove the plug "X" and open the compensating needle valve "U" two or three turns.

C. Start the engine and let it hunt for about thirty seconds at idling speed.

D. Gradually close the needle valve "U" until hunting stops or until it is only about ⅛ turn open.

E. If this does not stop the hunting open the needle valve about one turn and raise the compensation adjusting pointer "V" about two graduations.

F. Close the needle valve gradually again as under (D).

G. Repeat procedure until hunting stops.

H. It is desirable to have as little compensation as possible. Closing the needle valve more than is necessary will make the governor slow to return to normal speed after a load change. Excessive dashpot travel, indicated by the compensation adjusting pointer being too far toward maximum position, will cause an excessive speed change when the load changes.

MAINTENANCE

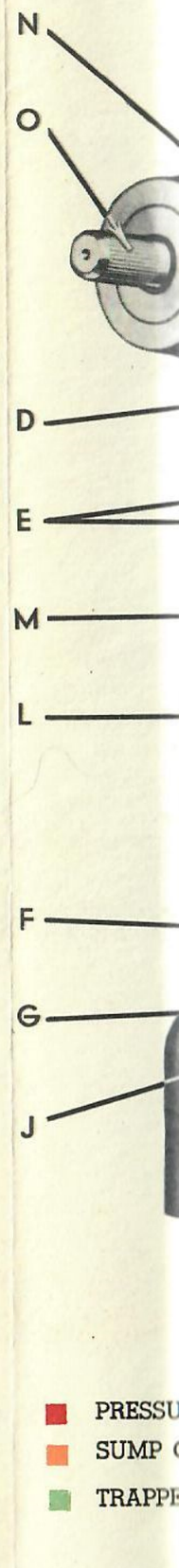
Use only the best grade of mineral lubricating oil in governor casing. It is important that the oil poured into the governor is new and clean, because any dirt entering the governor casing may prevent proper operation of governor. The container and funnel used for filling governor must be washed thoroughly in kerosene immediately before such use. The funnel should be provided with a fine mesh screen. The oil level in the governor should be maintained at the center of the sight glass. When changing oil, the governor casing should be flushed out with kerosene or clean light grade fuel oil.

When filling the governor for the first time or after renewal of the oil, bar engine over several revolutions to permit air to escape from the system. If the governor shows a tendency to hunt after oil renewal, open the compensating needle valve one or two turns for a few seconds to facilitate removal of air from the dashpot after which the needle valve must be returned to its previous setting.

For any maintenance work which requires disassembly of the governor or its components consult your Maintenance Bulletins, or have a Baldwin or Woodward service man do the work.

SPECIFICATIONS

GOVERNOR	NEW	LIMIT
Governor speed at 625 R.P.M. engine speed	1250 R.P.M.	
GOVERNOR DRIVE SHAFT		
Bushing to housing interference	.0005" - .0015"	
Shaft diameter	1.373" - 1.3725"	
Clearance	.002" - .0035"	.005"
Backlash for drive gears	.002" - .004"	.006"



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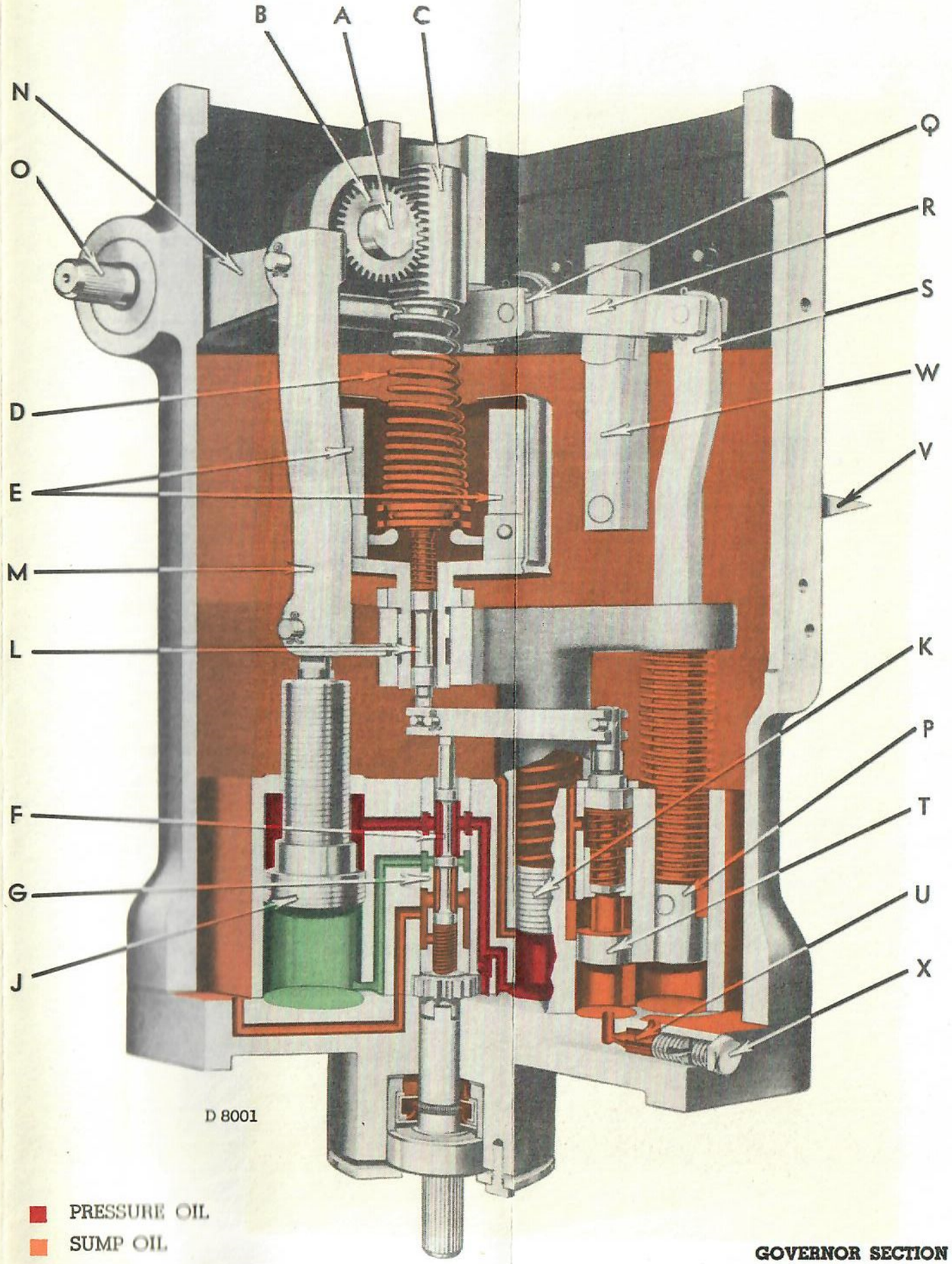
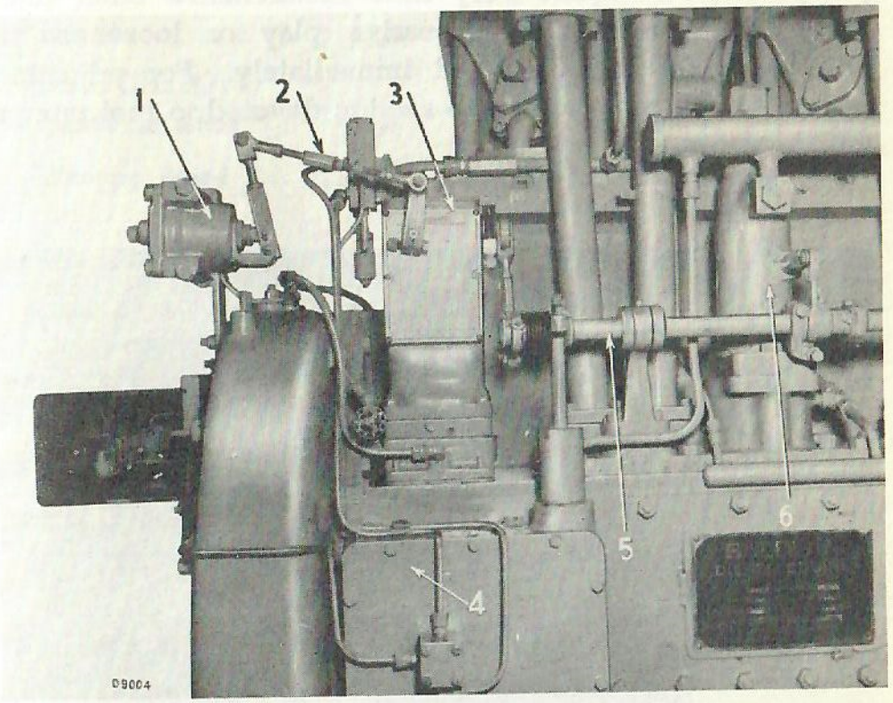


GOVERNOR SECTION
Figure 1

GOVERNOR CONTROL AND OVERSPEED STOP

The engine governor is controlled by an actuator which is pneumatically operated by the throttle valve in the cab. A linkage connects the actuator to the governor. Another linkage connects the governor to the fuel injection pump control shaft. This shaft extends along the length of the engine with connections to each fuel pump rack. For details of the pilot valve, metering valve, and carbonstat consult your Maintenance Bulletins.



GOVERNOR CONTROL

Figure 1

1. GOVERNOR ACTUATOR
2. GOVERNOR LINKAGE
3. GOVERNOR
4. OVERSPEED STOP
5. FUEL CONTROL SHAFT
6. FUEL INJECTION PUMP

OVERSPEED STOP

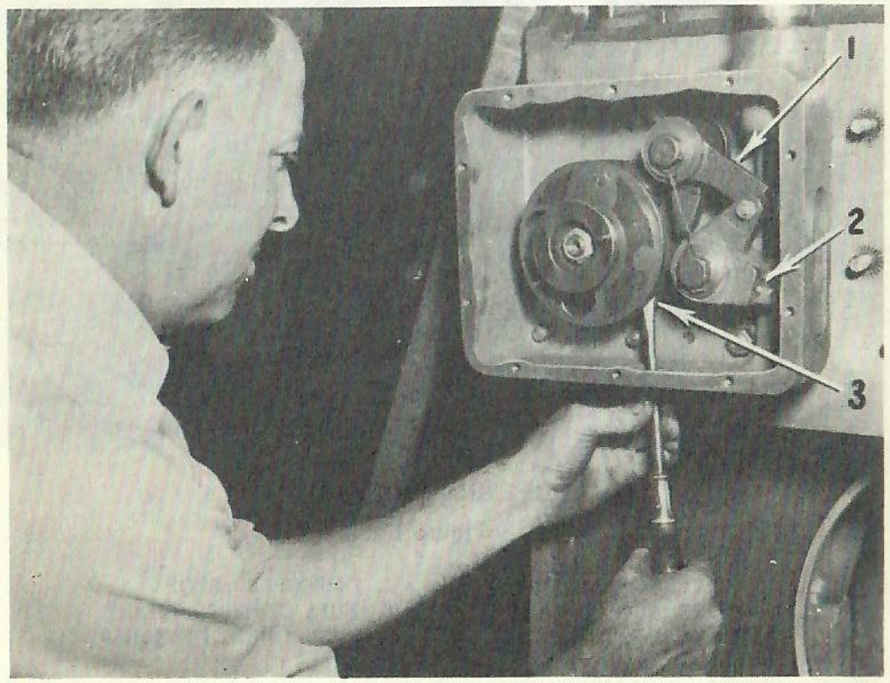
The overspeed stop is a device whose function is to shut down the engine in the event the speed of engine should exceed the maximum safe limit. It is driven by bevel

gears from the camshaft at twice engine speed and is located directly below the engine governor. Normally the overspeed stop is set to trip at an engine speed approximately 10% higher than the rated maximum speed. A weight, whose centrifugal force is balanced by a spring until the engine speed reaches the tripping point, actuates the stop.

MAINTENANCE

GOVERNOR CONTROL

The governor control linkage thru to the fuel injection pumps should require very little maintenance other than lubrication periodically. Excessive play or looseness in linkage should be corrected immediately. For adjusting pumps to balance engine see section devoted to fuel pumps and injectors.



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ADJUSTING OVERSPEED STOP

Figure 2

1. LATCH LEVER
2. HOLE FOR RESETTING BAR
3. TRIPPING SPEED ADJUSTMENT

OVERSPEED STOP

The overspeed stop tripping speed may be adjusted by turning the spring adusting screw. See Figure 2. This changes the spring pressure on the weight so that the centrifugal force necessary to trip the fuel shaft is altered. To reset the overspeed stop, insert a one-half inch diameter bar or a screw driver into the housing to engage the tripping lever. See Item 2, Figure 2. Pry downward until the mechanism is reengaged.

If after resetting the overspeed stop, the engine continues to be shut down by overspeeding, the cause should be determined and corrected.

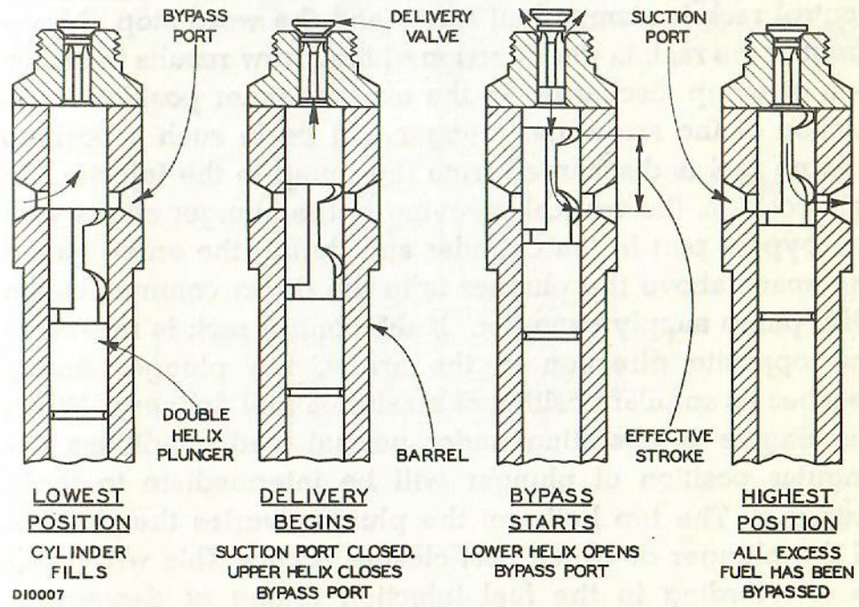
SPECIFICATIONS

OVERSPEED STOP	NEW	LIMIT
Tripping Speed	1375 R.P.M.—speed of overspeed shaft (this shaft runs twice engine speed)	
Backlash for drive gears.....	.002"-.004"	.006"

FUEL INJECTION PUMPS AND FUEL INJECTORS

FUEL INJECTION PUMP

The fuel pump is of the constant stroke type and an individual pump is provided for each cylinder. The pumps deliver the oil properly timed to the fuel injectors. The pump elements consist of an accurately ground and lap-fitted steel plunger and cylinder assembly. The plunger and its guide are held by a spring against a tappet and roller guide assembly, which are caused to reciprocate by the fuel pump cam. The fuel enters the chamber through the header connection. The quantity of fuel delivered by the pump is altered by changing the angular position of the plunger in respect to the pump cylinder. This is accomplished by means of a control rack which is connected to the governor thru the fuel control shaft.



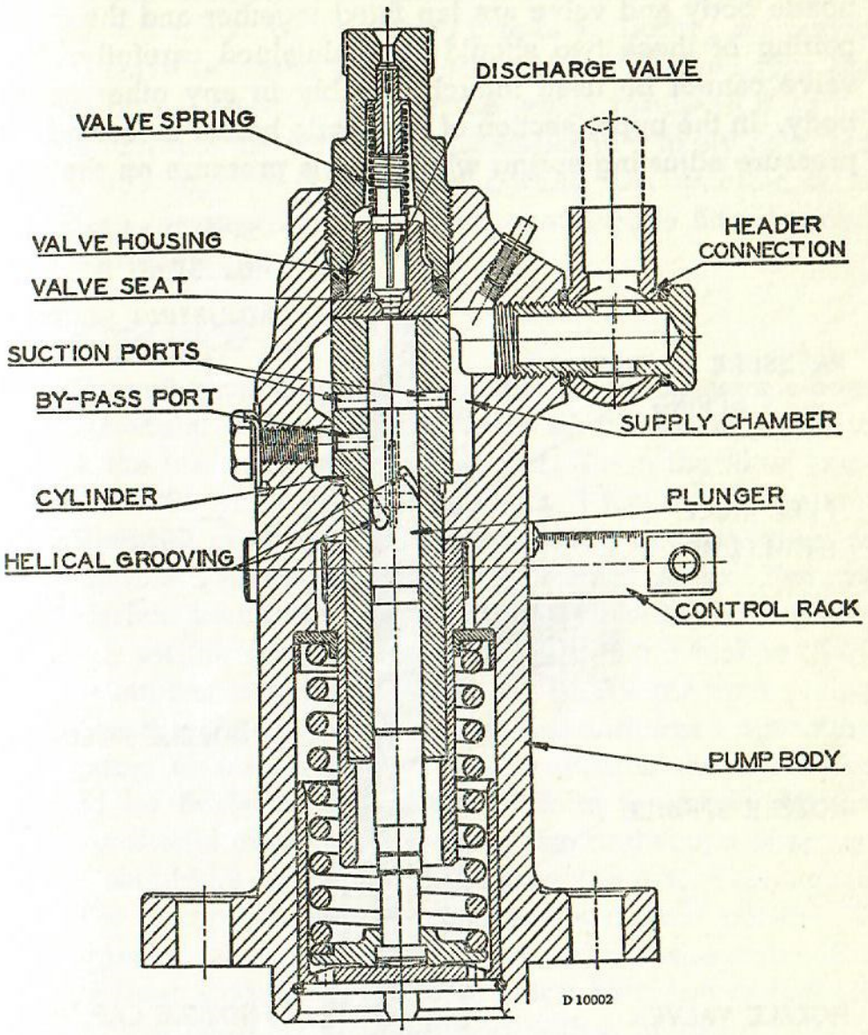
OPERATION OF FUEL PUMP

Figure 1

Operation of the fuel injection pumps is illustrated on Fig. 1. When the plunger is at the bottom of its stroke, the cylinder ports are uncovered. Oil is then delivered into the pump cylinder and fills the clearance space above plunger. On the upstroke of plunger, part of the fuel is displaced back

thru the suction port until the upper helix on the pump plunger covers this port, after which the oil remaining in the cylinder is forced thru the pump discharge valve to the injector in the engine cylinder head. Delivery of fuel to the injector continues as long as the cylinder ports are covered by the plunger. As the plunger moves toward the top of the stroke, the lower helix on the plunger will start to uncover the bypass port. During the balance of the upward stroke of plunger, the pump supply chamber is connected to the space above the plunger, permitting the fuel displaced by further upward plunger movement to return to the supply chamber. The effective pump plunger stroke is thus controlled by the angular position of plunger in respect to the pump cylinder.

The slopes of the upper and lower helixes on the plunger are so arranged that close regulation of fuel pump discharge is obtained by small movements of the control rack by the governor thru the common control shaft. At one end of each control rack is stamped an arrow and the word stop. Movement of the rack in the direction of the arrow results in reduction of pump discharge. In the extreme inner position in direction of the arrow the plunger will be in such a position that no fuel is discharged from the pump to the injector. In this position, the vertical grooving of the plunger aligns with the bypass port in the cylinder and during the entire stroke the space above the plunger is in the direct communication with pump supply chamber. If the control rack is moved in the opposite direction to the arrow, the plunger finally reaches its angular position of maximum fuel delivery. When the engine is operating under normal load conditions the angular position of plunger will be intermediate to these extremes. The top helix on the plunger varies the position of the plunger at which port closure occurs. This will result in a retarding in the fuel injection timing at decreasing rack settings and will make engine operation much smoother at lower speeds and loads. The upper helix exists from zero fuel position up to 18 mm. From this point on to the maximum fuel position, the point of port closure is fixed as would be the case in a single helix pump.

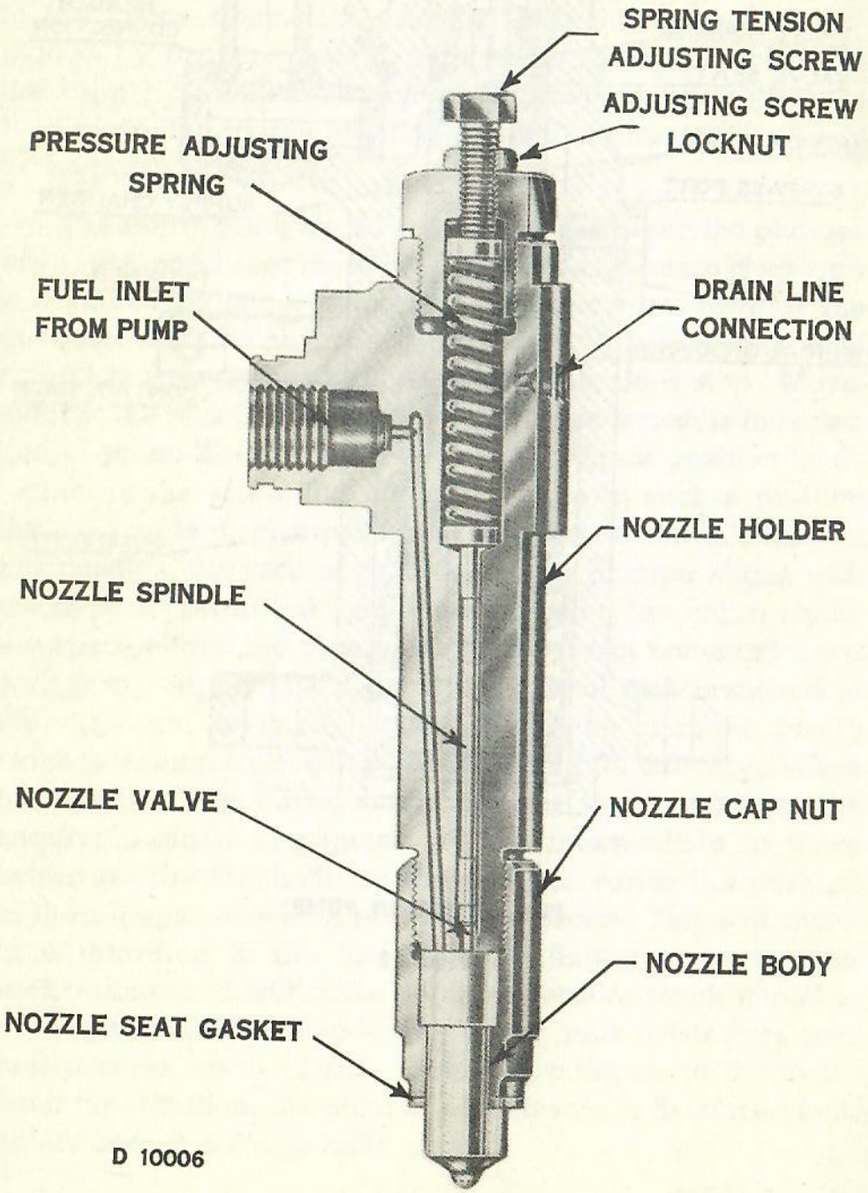


FUEL INJECTION PUMP

Figure 2

FUEL INJECTION

The fuel injector is illustrated on Fig. 3. The injector consists of a nozzle holder and nozzle body with valve. The nozzle body and valve are lap fitted together and the initial pairing of these two should be maintained carefully. The valve cannot be used interchangeably in any other nozzle body. In the upper section of the nozzle holder is located the pressure adjusting spring which exerts pressure on the nozzle spindle. The nozzle valve contacts this spindle and is seated by pressure of the spring. The valve is opened when fuel is delivered thru the passage under sufficient pressure to lift the valve against the spring pressure. During the period when valve is raised off the seat, oil is delivered thru the nozzle orifice under high pressure which results in delivery of the fuel into the combustion chamber in a finely atomized state. The injector is protected against dirt entering from the high pressure line by a small metal edge filter located in the fuel inlet line.



FUEL INJECTOR
Figure 3

MAINTENANCE

Consult your maintenance chart for the injector cleaning schedule. Remove one injector at a time in order to check the fuel spray in the open air. Clean the filter mentioned above when cleaning injectors. A fuel injection pump can be used as a hand pump for testing injector spray or if available use a standard injector testing device. Remove any carbon from injector nozzle tip. If a fuel injection pump is used, set the control rack in the normal full fuel position. A few strokes may be required to remove air from piping and injector. After the air is expelled and when operating the pump or tester quickly, the spray from the nozzle tip should be finely atomized and uniform in shape. All the orifices should discharge the same size and shape of spray. There should be no dribble when pumping action is stopped or after pump plunger has passed its cut-out position. If the injector does not function properly, disassemble the nozzle body and valve. Wash in clean kerosene or fuel oil. The orifice holes may be cleaned with a fine drill or wire of suitable size (see SPECIFICATIONS). Work the valve in the nozzle body in a pumping action under the surface of clear kerosene or fuel oil, then air, and observe whether or not the valve moves freely in any position in the nozzle body. Do not use lapping compound of any type. When nozzle difficulties cannot be rectified by careful cleaning, install a new nozzle and valve assembly. Return the defective valve and nozzle to Baldwin Locomotive Works, Diesel Service Department for reconditioning. The final assembly of the valve and nozzle should always be done with the parts submerged under the surface of clean fuel oil. Do not overtighten the cap nut so as to cause the valve to bind in

the nozzle. After assembling the injector, check the valve unseating pressure if an injector testing device is available. The opening press should be approximately 4000 pounds and can be altered by turning the adjusting screw inside the cap nut on top of nozzle holder.

The injection pumps should be checked on a test stand rather than on the engine. The pumps should operate freely and produce the same size spray for each stroke. If the pump action is irregular or does not discharge a sufficient amount of fuel during each stroke, the pump should be disassembled for inspection. Inspect the discharge valve, valve seat and valve spring and make corrections or replacements as required. The valve and valve seat are lap fitted and original pairing of these parts must be maintained. Remove the plunger and cylinder from the pump body. Each plunger and cylinder assembly is lapped to a precision fit and therefore these parts are not interchangeable. If any pump plunger and cylinder requires servicing, return the complete assembly to Baldwin Locomotive Works, Diesel Service Dept. When reassembling a pump, tighten the delivery valve holder with a torque wrench to 650 ft. lbs.

After pumps and injectors have been reassembled on engine, the system should be primed before starting the engine, although not to the extent that oil will be pumped into the cylinders as this condition will cause excessive firing pressures when the engine is started.

CYLINDER LOAD DISTRIBUTION

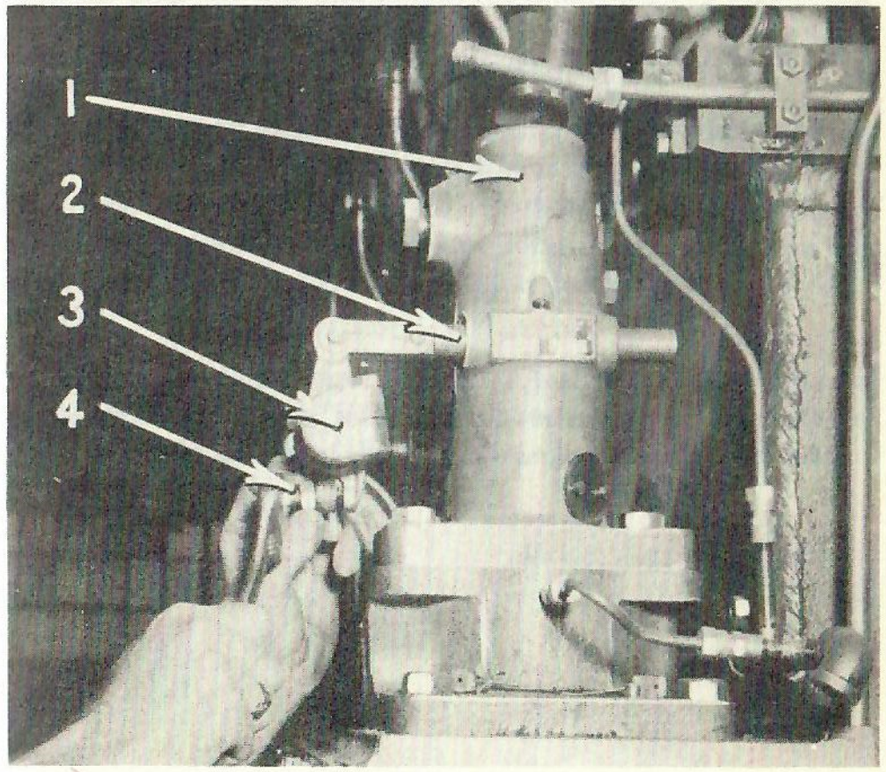
Exhaust temperature variations between cylinders is an indication of the load distribution between cylinders. If the engine is not provided with pyrometer equipment, use a portable pyrometer or a thermometer (1000° F. Scale). Exhaust temperature difference between cylinders should not vary more than 50° F. for supercharged engines and 100° F. for normally aspirated engines.

Before adjusting any fuel pumps for load distribution make sure the injection equipment is functioning properly as outlined in foregoing paragraphs. Also the fuel injection timing must be correct as described in engine timing section.

Any adjustment should be made only after engine is thoroughly warmed up and operating under reasonably

steady load. The load distribution between cylinders is altered by the adjustment screw mounted in an actuating lever on the fuel control shaft at each fuel pump. The screw and lever actuate the floating lever connected to each fuel pump rack. By turning screw clockwise the fuel discharge is increased and counter clockwise decreases the fuel discharge. The adjusting screw should be turned only about one-half turn at a time until proper load distribution is obtained. After the correct adjustment is obtained, the lock nut should be tightened on the adjusting screw.

On the control rack of each fuel pump are stamped millimeter graduations indicating load position of the plunger. However these graduations should not be used as



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BALANCING FUEL PUMPS

Figure 4

1. FUEL INJECTION PUMP
2. CONTROL RACK
3. FUEL CONTROL SHAFT
4. RACK ADJUSTING SCREW & LOCK-NUT

a basis for readjusting any fuel pumps for load distribution. When injection equipment is in good condition, and the load between cylinders properly equalized the maximum variation in rack setting of all pumps should not exceed 2 mm. If the variation in rack setting is greater, the injection system should be inspected and replacement or reconditioning of parts done as required.

SPECIFICATIONS

FUEL INJECTOR

Opening pressure	4000 P.S.I.
Number of holes	9
Diameter of holes	.0177"
Spray angle	150°

CYLINDER CONDITIONS AT FULL LOAD	Supercharged 8 Cylinder	Supercharged 6 Cylinder
Compression pressure—P.S.I.	750 ± 30	720 ± 30
Maximum firing pressure—P.S.I.	1,000 ± 25	970 ± 25
Exhaust elbow temperature—°F.	900 ± 25	850 ± 25

	Normally Aspirated (750 H.P.) 6 Cylinder	Normally Aspirated (660 H.P.) 6 Cylinder
Compression pressure—P.S.I.	540 ± 20	520 ± 20
Maximum firing pressure—P.S.I.	1,015 ± 25	825 to 850
Exhaust elbow temperature—°F.	950 ± 50	950 ± 50

AUXILIARY CHAIN DRIVE

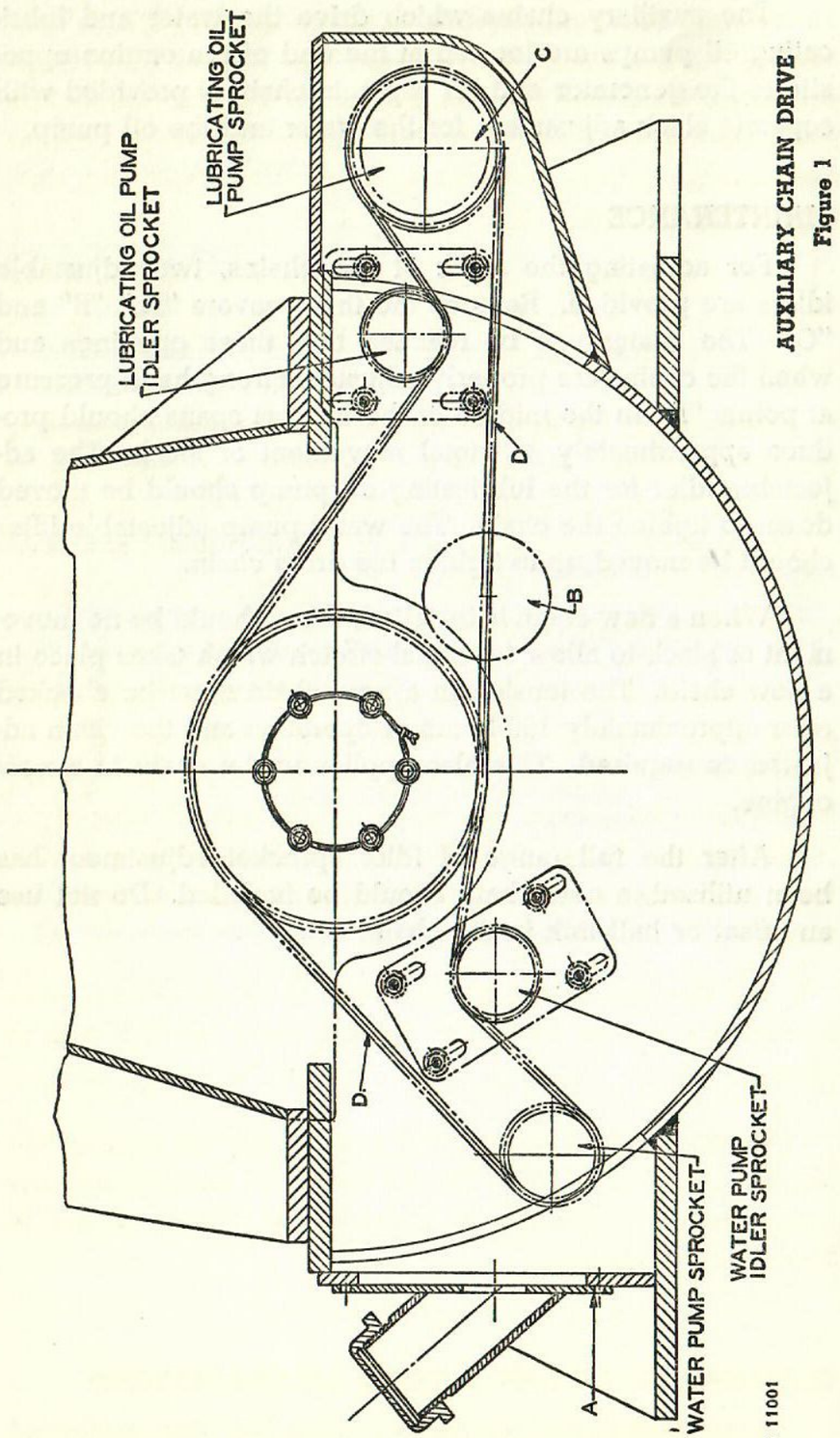
The auxiliary chains which drive the water and lubricating oil pumps are located at the end of the engine opposite to the generator end. A separate chain is provided with separate slack adjustment for the water and the oil pump.

MAINTENANCE

For adjusting the slack of the chains, two adjustable idlers are provided. Remove the three covers "A," "B" and "C." The chains can be reached thru these openings and when the chains are properly adjusted, strong hand pressure at points "D" in the middle of the longest spans should produce approximately ¼" total movement or slack. The adjustable idler for the lubricating oil pump should be moved down to tighten the chain. The water pump adjustable idler should be moved up to tighten the drive chain.

When a new chain is installed, there should be no movement or slack to allow for initial stretch which takes place in a new chain. The tension in a new chain must be checked after approximately 150 hours of operation and the chain adjusted as required. This also applies to the chain in a new engine.

After the full range of idler sprocket adjustment has been utilized, a new chain should be installed. Do not use an offset or half link in the chain.



AUXILIARY CHAIN DRIVE
Figure 1

COOLING WATER SYSTEM

The cooling water system is of the closed type. A centrifugal pump, chain driven from the engine crankshaft, circulates the water thru the engine jackets to the cooling radiators and thence thru the lubricating oil heat exchanger before returning the water to the engine. An expansion tank is provided for the system.

On locomotives equipped with lube oil radiators instead of heat exchangers the water goes directly to the engine from the radiators.

Any water regardless of source should be subjected to chemical analysis, in order to determine the suitability of the water for diesel engine cooling. Although it may appear clean and pure, water in general contains impurities as suspended matter, chemicals which are classified as "hardness" in the water, excess oxygen, and acids.

Suspended matter and oil in the water, even in the smallest degree, will impair the proper heat transfer condition of the system. Sludge and mud will form and excessive foaming occur if the oil and suspended matter are not filtered out of the water. Proper coagulation and passage thru a sand filter will remove the oil and suspended matter from the water.

See Maintenance Bulletin MBG-109 for additional information on water treatment and flushing of the cooling system.

When draining the cooling system, do not drain while engine is hot (over 120° F.). All sediment which may have accumulated at the bottom of the water jackets should be flushed out carefully.

CLEANING OF ENGINE JACKETS AND RADIATORS

If the condition of the cooling water has been neglected, causing scale to deposit in engine jackets and radiators, it

should be removed as soon as possible. A chemical solution such as Oakite No. 32 made by Oakite Products Inc., New York, N. Y., or Dearborn No. 134 made by Dearborn Chemical Co., Chicago, Ill., may be used. Instructions furnished by the manufacturer of the cleaning compound should be followed carefully. It is important to thoroughly flush and neutralize the system after cleaning.

When refilling the system, use only treated water. Operate the engine a few minutes to expel any air trapped in the system, after which water is added to completely fill the system. Make up water should be added to the system when engine is not in operation and preferably when engine is cold. If make up water must be added to system while engine is warm above (120° F.), the water should be heated or added to the system very slowly.

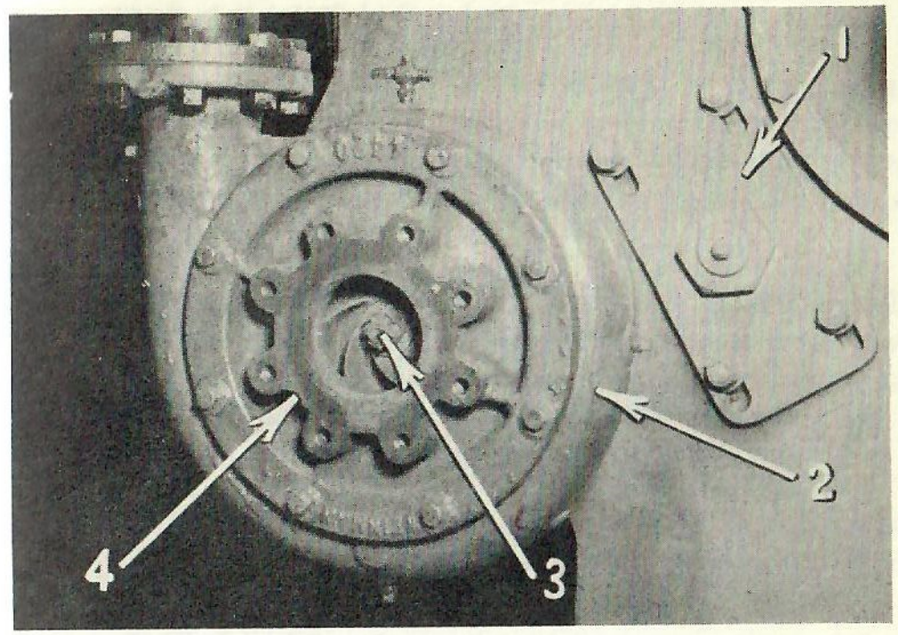
WATER CIRCULATION AND TEMPERATURE

The cooling water temperature may vary between 145° F. and 175° F. depending on engine load and atmospheric conditions, although safe operation can be achieved with temperatures up to 200° F. Radiators cooled by either engine or motor driven fans remove the heat from the engine cooling water. Consult the Operator's Manual for your locomotive for more details on the external water system.

Some locomotives are equipped with a hot water shut down device which will actuate the fuel injection pump control shaft thus shutting the engine down should the water exceed 200° F. See Figure 5 in Lube Oil Section.

WATER PUMP

The water pump requires no outside lubrication. The bearings are lubricated by the crankcase oil.



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WATER PUMP
Figure 1

1. CHAIN IDLER ADJUSTMENT BRACKET
2. PUMP CASING
3. IMPELLER NUT (LEFT HAND THREAD)
4. PUMP SUCTION HEAD

MAINTENANCE

The entire pump unit should be removed from engine for bearing replacement (see Maintenance Bulletin). Spread a thin film of permatex on the frame when replacing pump and gasket. When the nuts on the packing gland can no longer be taken up to stop water leakage, the pump packing should be replaced. In installing the new packing rings, rotate the ring gaps 180° apart on each successive ring to cut down the leakage. Do not tighten the packing gland too tightly after installing new packing or the pump shaft might become scored. After the packing has been run in, the gland should be tightened until there is only a small but constant drip of water from it.

SPECIFICATIONS

Water Pump Capacity in GPM..... 500

FUEL SUPPLY SYSTEM

The fuel oil is pumped from the tank by means of a motor-driven supply pump. A strainer is provided in the suction line to protect the supply pump. A cartridge type filter is located in the pressure line between the supply pump and the injection pumps.

In the suction line to the supply pump is located a fuel shut-off valve which can be manually operated from the cab or from the outside in an emergency. A relief valve is provided in the supply pump discharge set to open at approximately 35 pounds pressure.

A relief valve set to open at approximately 25 pounds is connected to the fuel injection pump supply header. The excess oil supplied to the header returns to the fuel tank thru this relief valve.

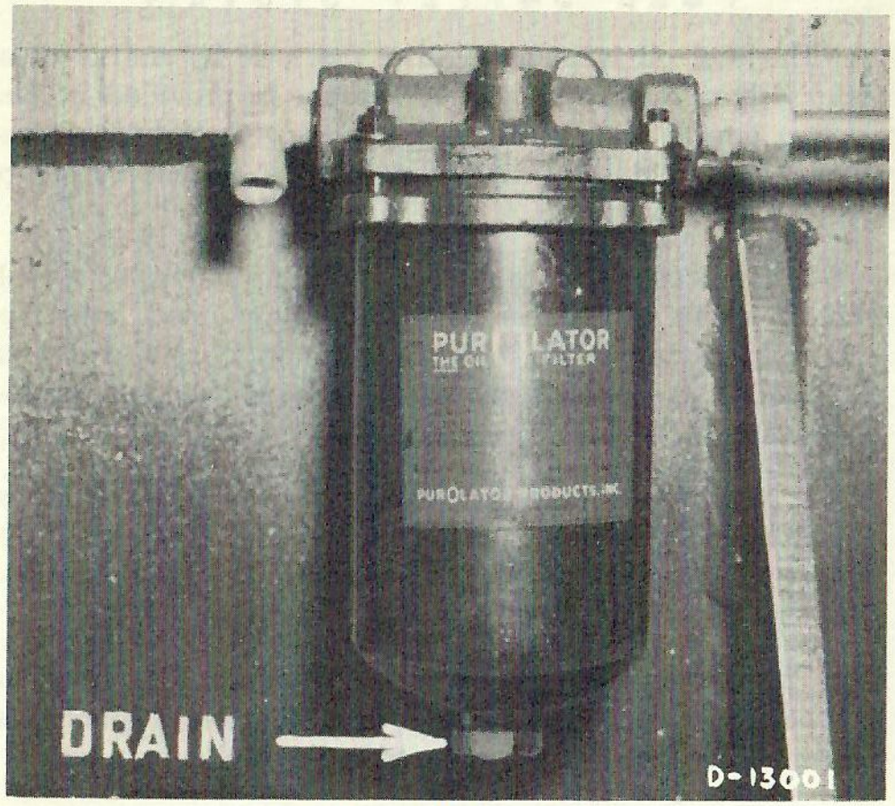
The fuel injection pumps and injectors are described in a separate section. Any leakage from injectors or pumps is collected in a header and returned to the fuel supply tank.

A protective system actuates the fuel injection pump control shaft and shuts the engine down in case dangerous conditions occur which are controlled by safety switches. This system is described under Lube Oil System.

FUEL OIL PURIFICATION

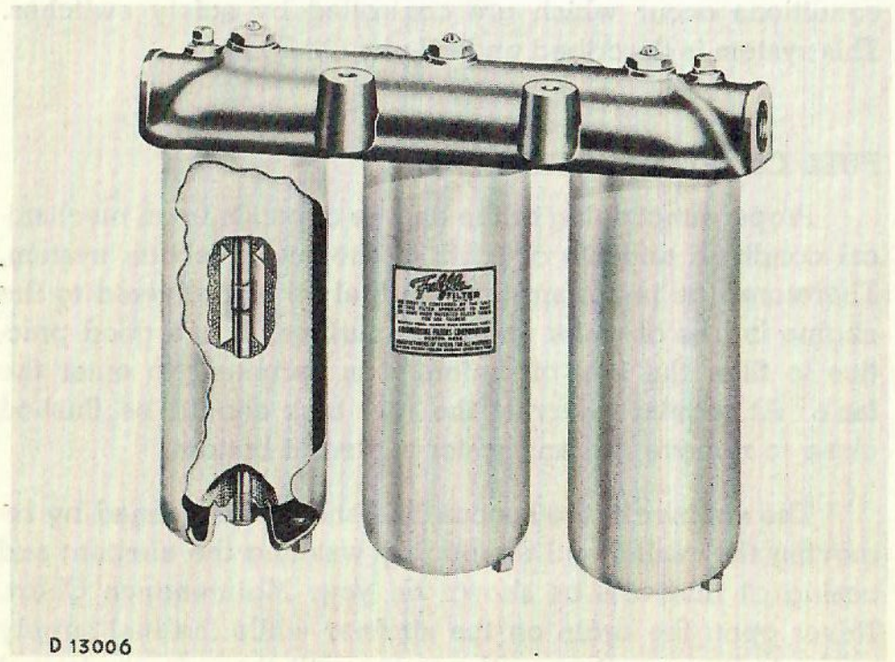
Proper functioning of the engine depends upon mechanical condition and fits of parts of the fuel injection system. Therefore it is important that the fuel oil as delivered to the engine is free of water and all impurities. It is a good practice to filter the fuel oil before it is permitted to enter the tank. At regular intervals the fuel tank should be flushed clean to remove dirt and water settled at bottom.

The strainer in the suction line should be cleaned by removing the casing and thoroughly washing the element and casing at intervals as shown on your Maintenance Chart. Never open the drain on the strainer while the fuel supply pump is in operation as the pump will then draw air and lose its prime.



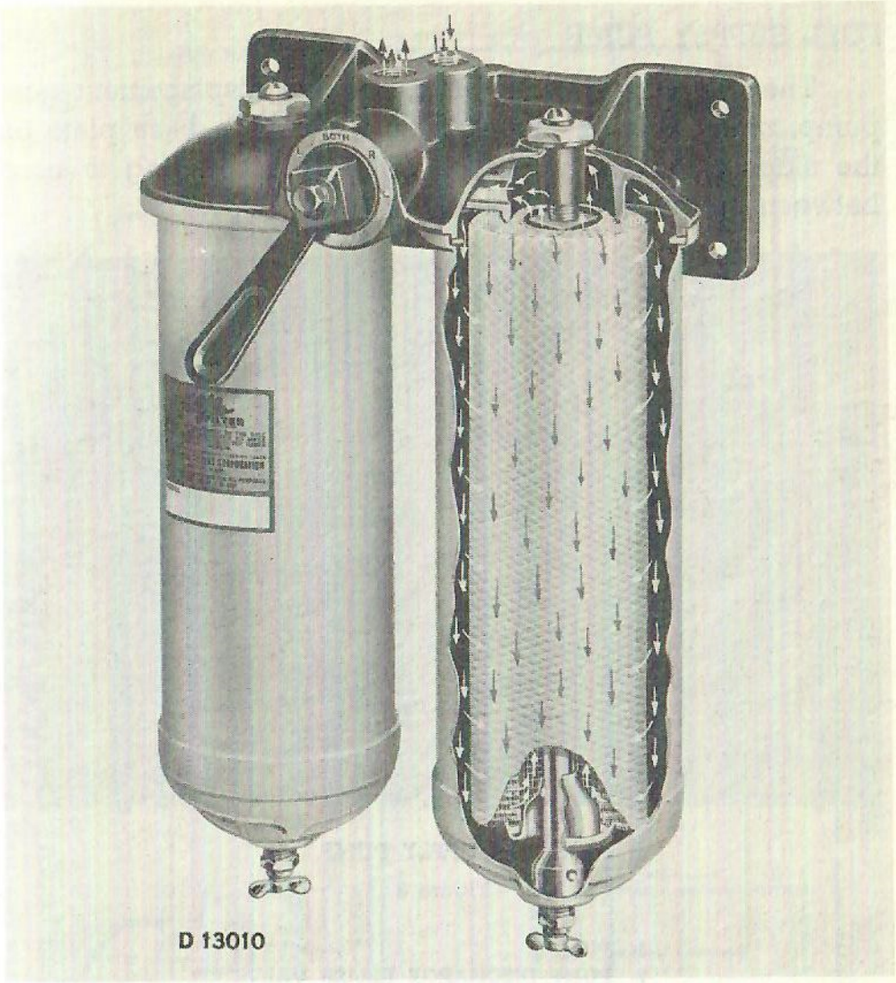
FUEL OIL SUCTION STRAINER

Figure 1



FUEL OIL PRESSURE FILTER

Figure 2



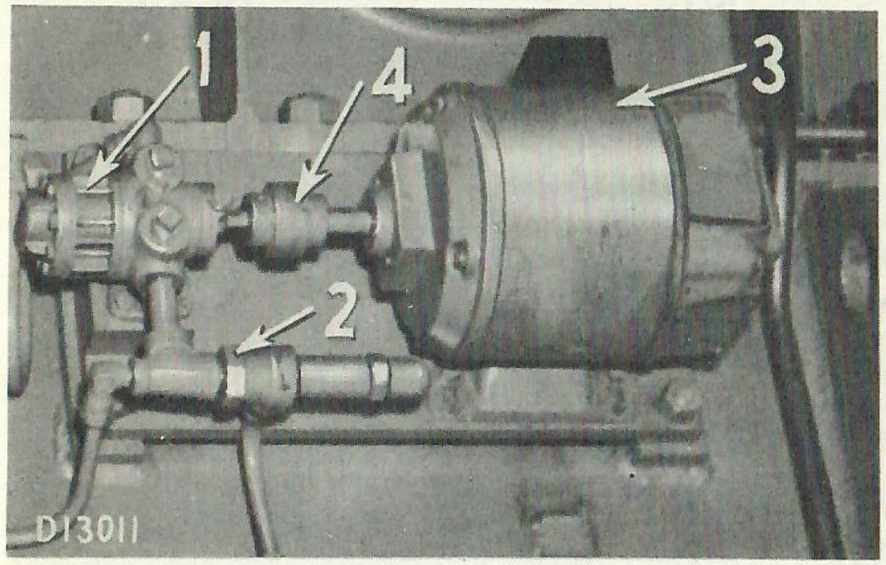
FUEL OIL DUPLEX FILTER

Figure 2A

Open the drain plug at the bottom of the pressure filter to drain off dirt and water. This should be done while the supply pump is in operation. If the pressure in the fuel injection supply header drops below normal it may indicate the filter is becoming clogged. The cartridge should then be replaced. However, it is best to renew the cartridge as indicated on your Maintenance Chart. After renewal of the filter element it will be necessary to open the vent on the top of the filter to permit the air to escape. The system is cleared of air by operating the supply pump until all air has been expelled from filter and piping.

FUEL SUPPLY PUMP

The fuel supply pump is a positive displacement gear pump, motor driven, mounted on a common base plate on the side of the engine base. A flexible coupling is used between the motor and pump.



FUEL SUPPLY PUMP
Figure 3

1. PUMP
2. PUMP DISCHARGE RELIEF VALVE
3. MOTOR
4. COUPLING

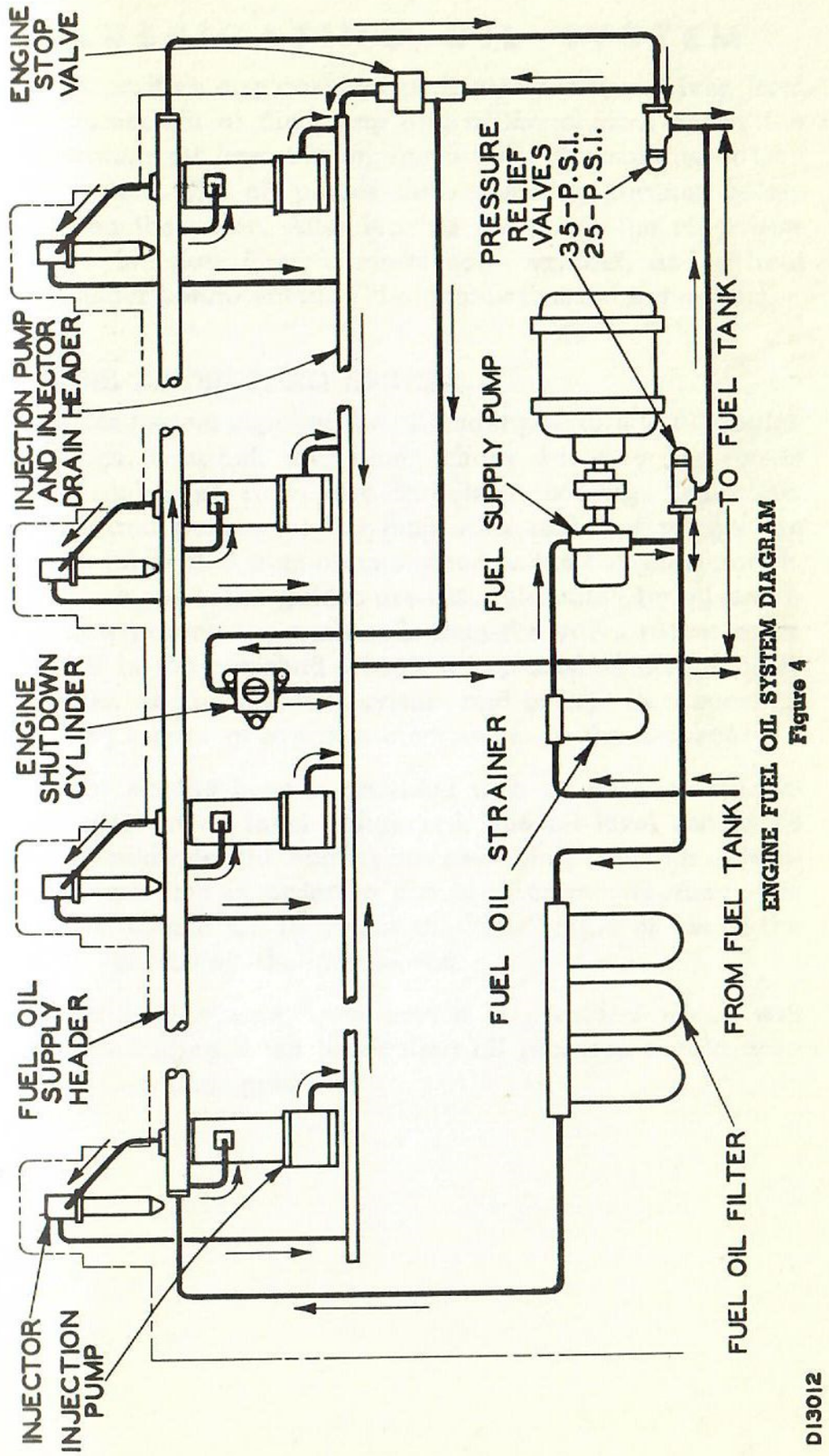
MAINTENANCE

The pump should be lubricated as indicated on your Maintenance Chart at the fitting provided on the coupling end.

Excessive noise or failure to maintain pressure should be investigated by dismantling the pump and checking all parts thoroughly. (Refer to the Maintenance Bulletin covering this pump.)

SPECIFICATIONS

Fuel Supply Pump Capacity in GPM at 35 P.S.I... 3



ENGINE FUEL OIL SYSTEM DIAGRAM
Figure 4

LUBRICATING OIL SYSTEM

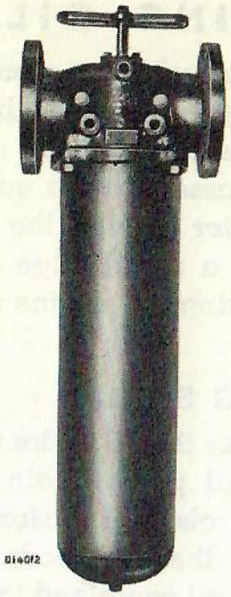
A positive displacement gear pump, chain driven from the crankshaft at the pump end of the engine, draws the lubricating oil from the engine base and circulates it thru the system. The oil passes thru a suction strainer before entering the pump. After leaving the pump the oil passes thru a full flow filter, a metal edge strainer, and a heat exchanger before entering the engine distributing system.

ENGINE DISTRIBUTING SYSTEM

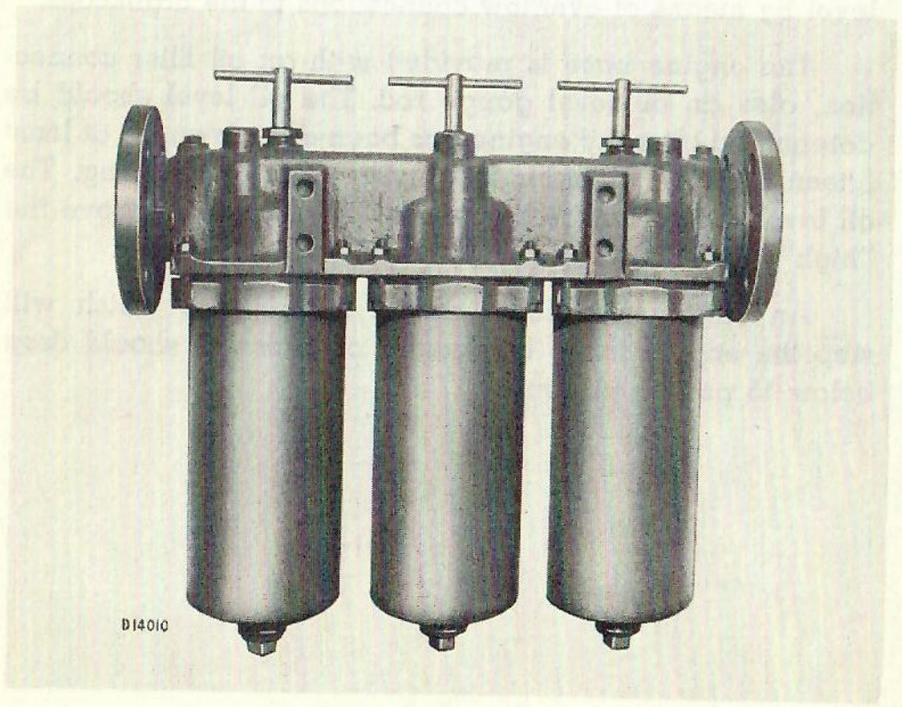
This system supplies the oil under pressure to all engine bearings, camshaft and pump chain drives, valve rocker arms and push rods, also for piston cooling. The cams, rollers and guides for the push rods and fuel pumps are splash lubricated from oil contained in the camshaft trough. The push rod roller guides are also lubricated by oil draining down along the push rods from the valve rocker arms. The oil in the camshaft trough is replenished continuously from the engine pressure system and is kept at a constant level by means of overflow connections to the crankcase.

The engine base is provided with an oil filler connection, also an oil level gauge rod. The oil level should be determined after the engine has been shut down for at least fifteen minutes in order to obtain a correct reading. The oil level should not be below the "low" mark or above the "high" marks on the gauge rod.

An engine shut-down device is provided which will stop the engine if the lubricating oil pressure should drop below 15 pounds pressure.



LUBRICATING OIL STRAINER
(Single Unit Type)
Figure 1

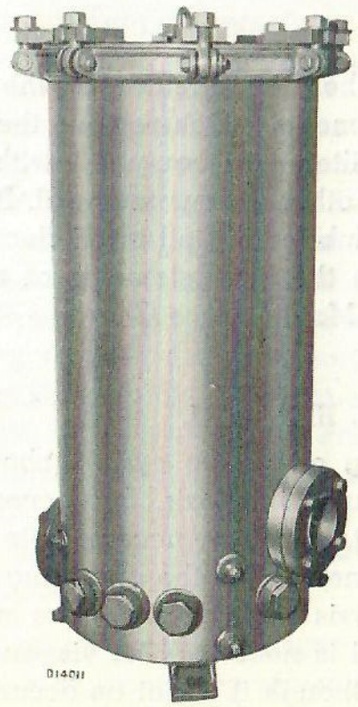


LUBRICATING OIL STRAINER
(Three Unit Type)
Figure 2

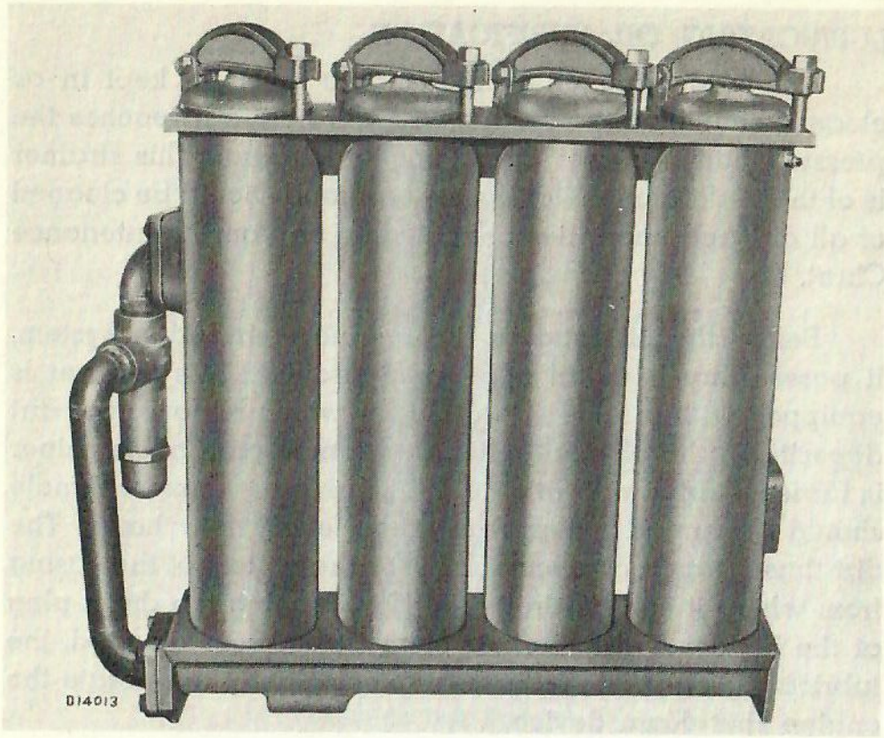
LUBRICATING OIL PURIFICATION

The lubricating oil in the engine must be kept in as clean a condition as possible. The oil, before it reaches the pressure pump, passes thru a suction strainer. This strainer is of the perforated metal basket type and should be cleaned of all dirt and impurities as indicated on your Maintenance Chart.

Before the oil reaches the engine distributing system, it passes thru a metal edge type strainer. This strainer is equipped with a knife edge scraper which removes the dirt deposits on the element when the handle on top of strainer is turned. During operation of the engine the scraper handle should be turned a few revolutions every four hours. The dirt thus scraped off accumulates at the bottom of the casing from where it can be drained off by opening the drain plug at the bottom. If the strainer element becomes clogged, the lubricating oil pressure may drop sufficiently to operate the engine shut-down device.



LUBRICATING OIL FILTER (CIRCULAR TYPE)
Figure 3



LUBRICATING OIL FILTER (FLAT TYPE)
Figure 4

The filters, either the circular or the flat type have absorbent type elements which remove the finer impurities in the oil. These filters are equipped with elements composed of waste or other fibrous material. It is necessary in order to keep the lubricating oil in as clean a condition as possible to change the filter elements at regular intervals as specified on the Maintenance Charts.

LUBRICATING OIL RENEWAL

The lubricating oil in the system should be changed completely at regular intervals. See recommendations on Maintenance Chart. It may be necessary to change the time period between renewals as the operating conditions vary. A laboratory analysis of a sample of the crankcase oil will indicate if renewal is necessary. A visgauge may be used for this purpose although it is not as accurate as a laboratory analysis.

The oil should be removed shortly after engine has

been shut down and while oil is still warm. Drain the oil from camshaft trough, heat exchanger, lubricating oil strainer and filters. Remove lubricating oil strainer casing and clean the element. Also check that the scraper functions properly. Repack the filters with new waste. Use a flushing oil for cleaning crankcase, heat exchanger, strainers and filters. Never use gasoline or waste to clean or wipe inside of engine. Always use clean cloths which do not deposit lint.

When adding new oil, fill crankcase up to the high mark on the gauge. Also fill camshaft trough until it overflows into the crankcase thru level pipes. Open vents on the strainer and filters. After the system is primed, check the oil level and add more oil as necessary to bring the oil level up to the high mark on the gauge rod.

LUBRICATING OIL PRESSURE

The lubricating oil pressure gauge should normally indicate a pressure of 65 pounds at rated speed. At lower speeds the pressure will be proportionately lower. At no time should the pressure drop below 15 pounds pressure.

If the lubricating oil pressure drops below 50 pounds, this may be caused by excessive dirt on the strainer element increasing the flow resistance. When the strainer element becomes clogged, undue by-passing of oil directly to the crankcase will take place thru the pressure relief valve in the by-pass line thus reducing the pressure and flow of oil to the engine. The strainer casing should be removed and the element and casing thoroughly cleaned. Also check the pressure relief valve in the by-pass line and make corrections as necessary. If the cleaning of the strainer and resetting the pressure relief valve does not correct the low pressure condition, the entire lubricating oil system should be inspected for undue restrictions or leaks.

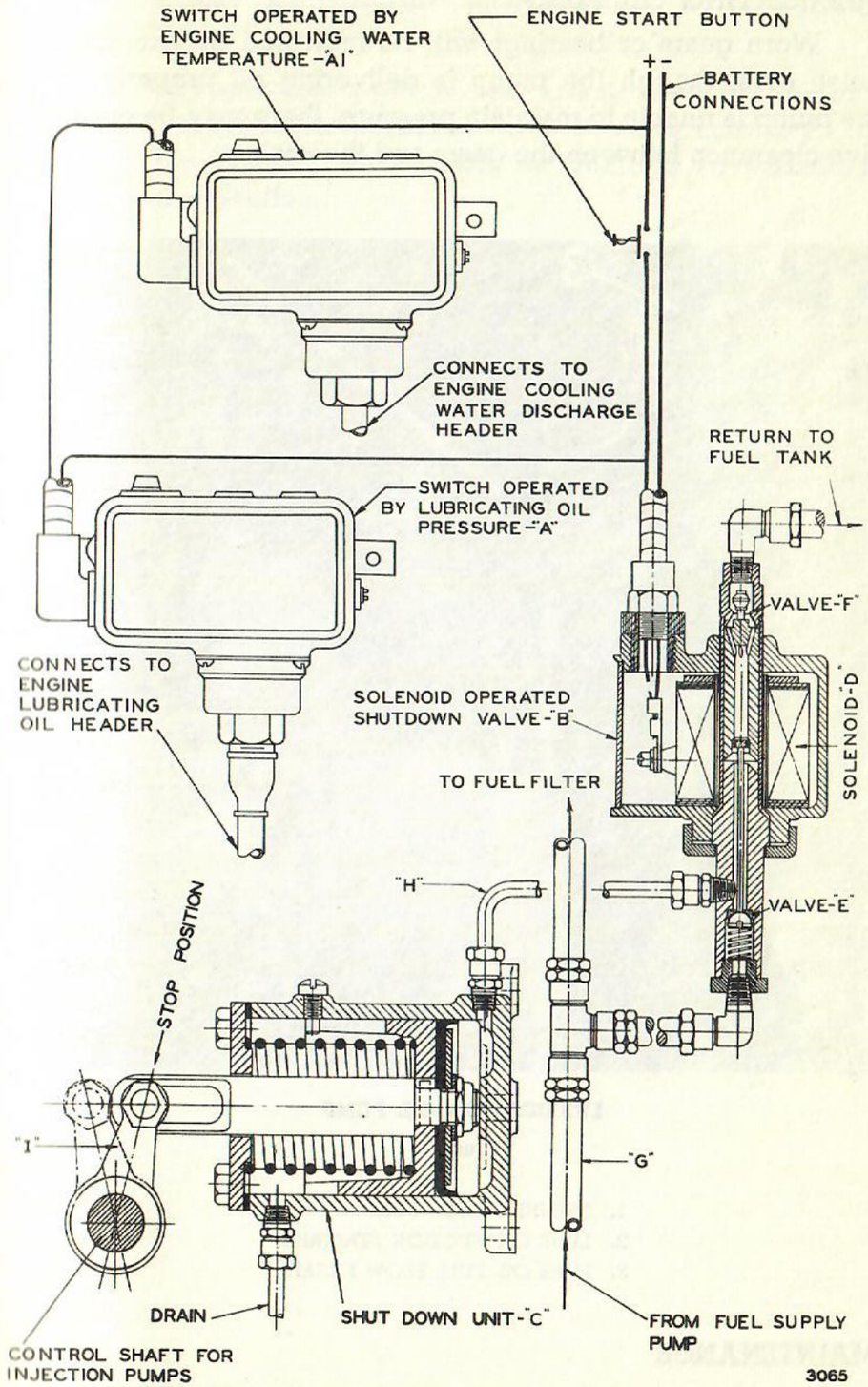
If the lubricating oil pressure is appreciably higher than 65 pounds, this may be caused by unusually heavy lubricating oil, undue restrictions in the lubricating oil system inside the engine, or sticking of the pressure relief valve in the by-pass line. Investigate and make corrections as necessary.

LOW LUBRICATING OIL PRESSURE SHUT DOWN

The engine protective shut-down system shown in Fig. 5 includes the low lubricating oil pressure switch which is set to shut down the engine if the lubricating oil pressure drops to approximately 15 pounds. This device consists of a pressure operated switch "A," a solenoid operated double acting valve "B" and a shut-down unit "C." The switch "A" is operated by the pressure in the lubricating oil system. During normal operation the switch "A" is held in the closed position by the lubricating oil pressure, thus permitting the electric current to energize the solenoid "D" which then keeps the valve "E" open and the valve "F" closed. When the valve "E" is open the fuel supply line "G" is in direct communication with the shut-down unit "C" thru the line "H." The piston inside the shut-down unit "C" is then pushed out by the fuel pressure thus moving the lever "I" to a position which releases the fuel pump control shaft from the stop position.

If the pressure in the lubricating oil header drops to 20 pounds or lower the switch "A" breaks the current to the solenoid "D" which then closes the valve "E" and opens the valve "F." The fuel under pressure in cylinder "C" is then released thru line "H" and valve "F" to the tank. When the fuel pressure in cylinder "C" is released the piston is pushed in the opposite direction by means of a spring. The lever "I" operated by the piston, then turns the fuel injection pump control shaft to the stop position thus shutting the engine down. A torsion spring at the governor end of the control shaft permits the shaft to turn to the stop position independently of the governor.

During the starting period when there is no pressure in the lubricating oil header to close switch "A," the solenoid circuit is closed by means of the engine starting button. The switch "A" requires approximately 19 pounds pressure for contact closing. The starting button must be held closed until the engine speed is sufficient to build up an oil pressure in excess of 19 pounds; otherwise, switch "A" would stop the engine. When the oil pressure is high enough to close switch "A" and the starting button is released, the circuit is complete through switch "A" to the solenoid valve "B."

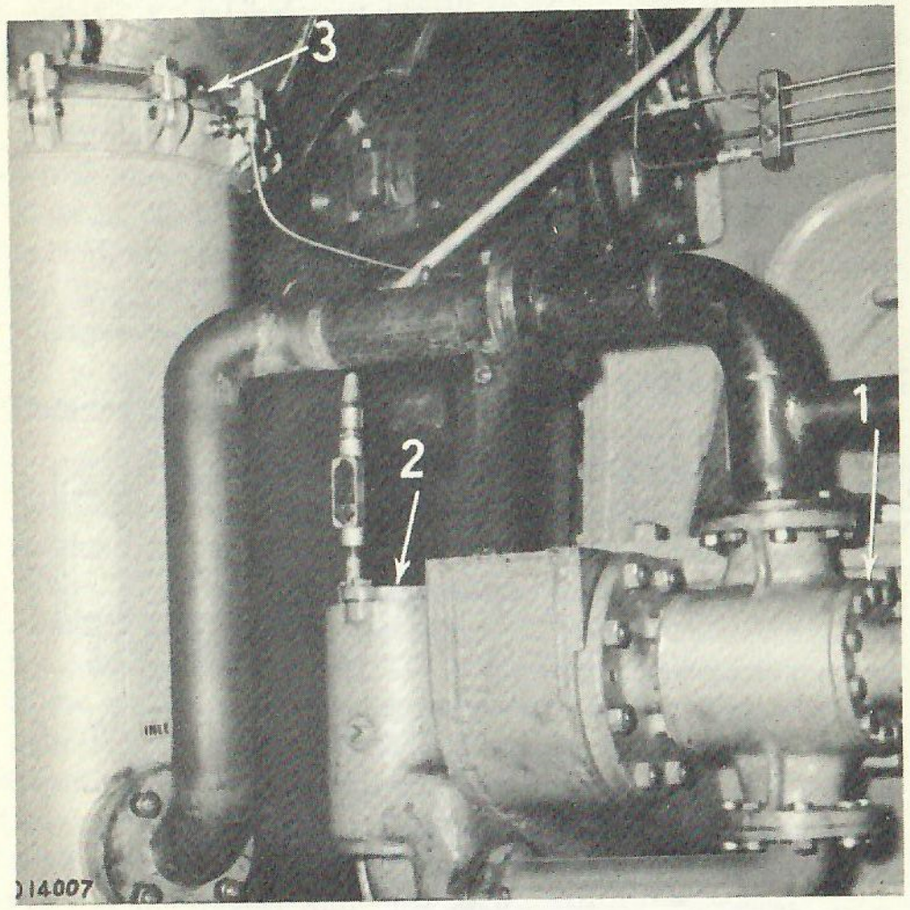


TYPICAL ENGINE PROTECTIVE SHUT-DOWN SYSTEM
(Including Low Lubricating Oil Pressure Switch)

Figure 5

LUBRICATING OIL PUMP

Worn gears or bearings will be indicated by excessive noise even though the pump is delivering oil properly. If the pump is unable to maintain pressure, there may be excessive clearance between the gears and the casing.



LUBRICATING OIL PUMP
Figure 6

1. ENGINE DRIVEN PUMP
2. LUBE OIL SUCTION STRAINER
3. LUBE OIL FULL FLOW FILTER

MAINTENANCE

In order to service the pump properly it should be removed from the engine. Disconnect the drive chain from the pump sprocket before removing the bolts which fasten the pump to the engine base. Remove the drive sprocket from

the shaft, also the key. The pump can then be completely disammbled. (See Maintenance Bulletin.)

When replacing a pump and gasket, use permatex on bedplate only. After the pump drive chain is connected, it should be checked for tension as outlined in Auxiliary Chain Drive Section.

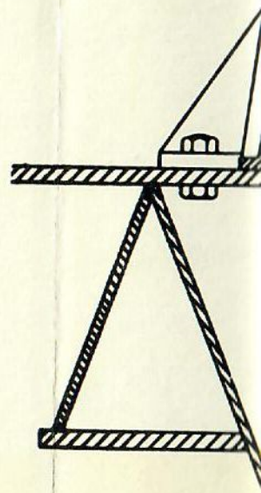
SPECIFICATIONS

Lubricating Oil Maximum Operating Temperature—°F	185
Lubricating Oil Pump Relief Valve Setting—P.S.I.	125
Lubricating Oil Header Relief Valve Setting—P.S.I.	65
Lubricating Oil Header (Rocker Arms) Relief Valve Setting—P.S.I.	10

L.O. HEADE
BLOCK

L.O. HEADER

CHAIN
LUBRICATION SPRAY



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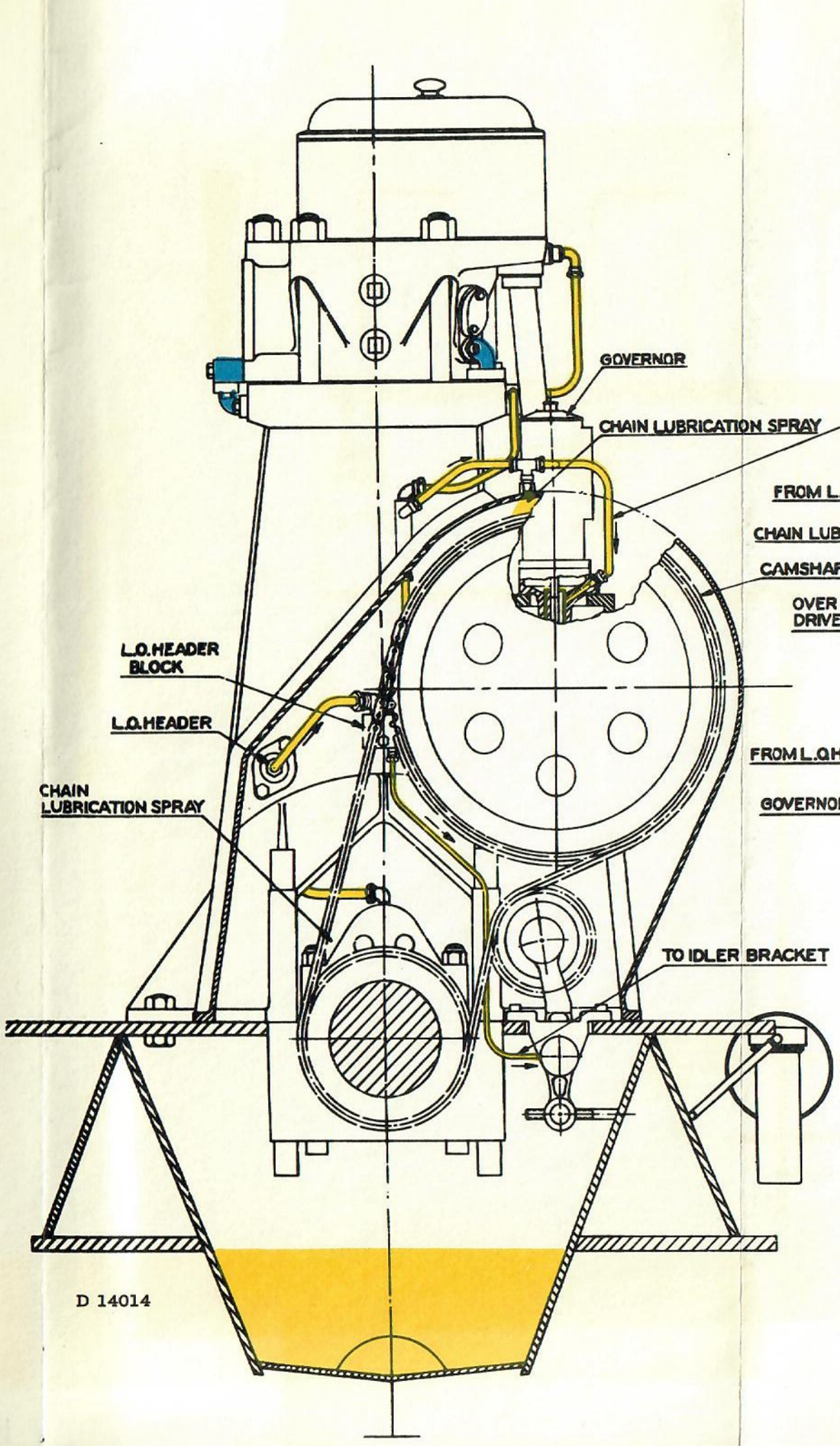
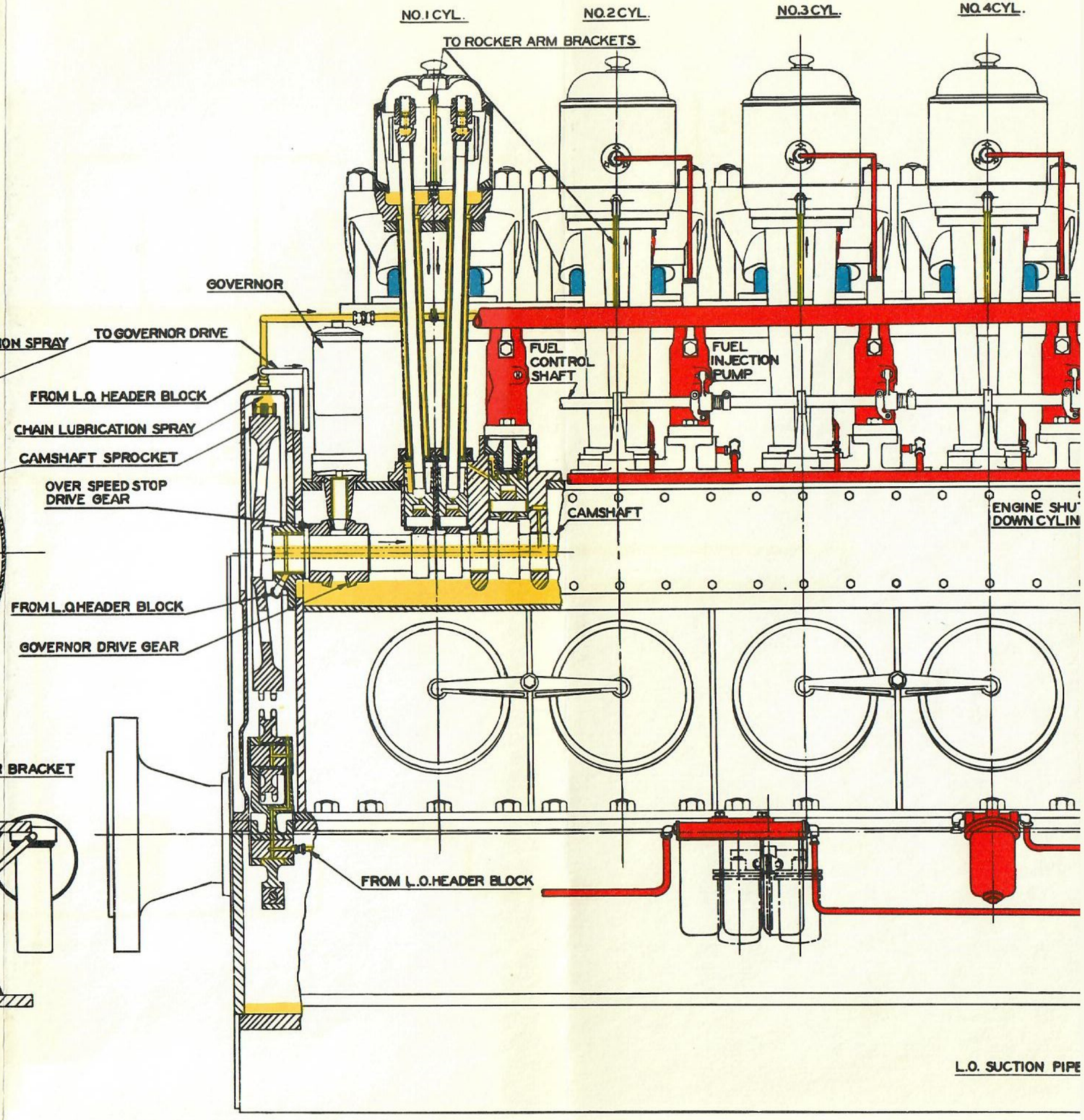
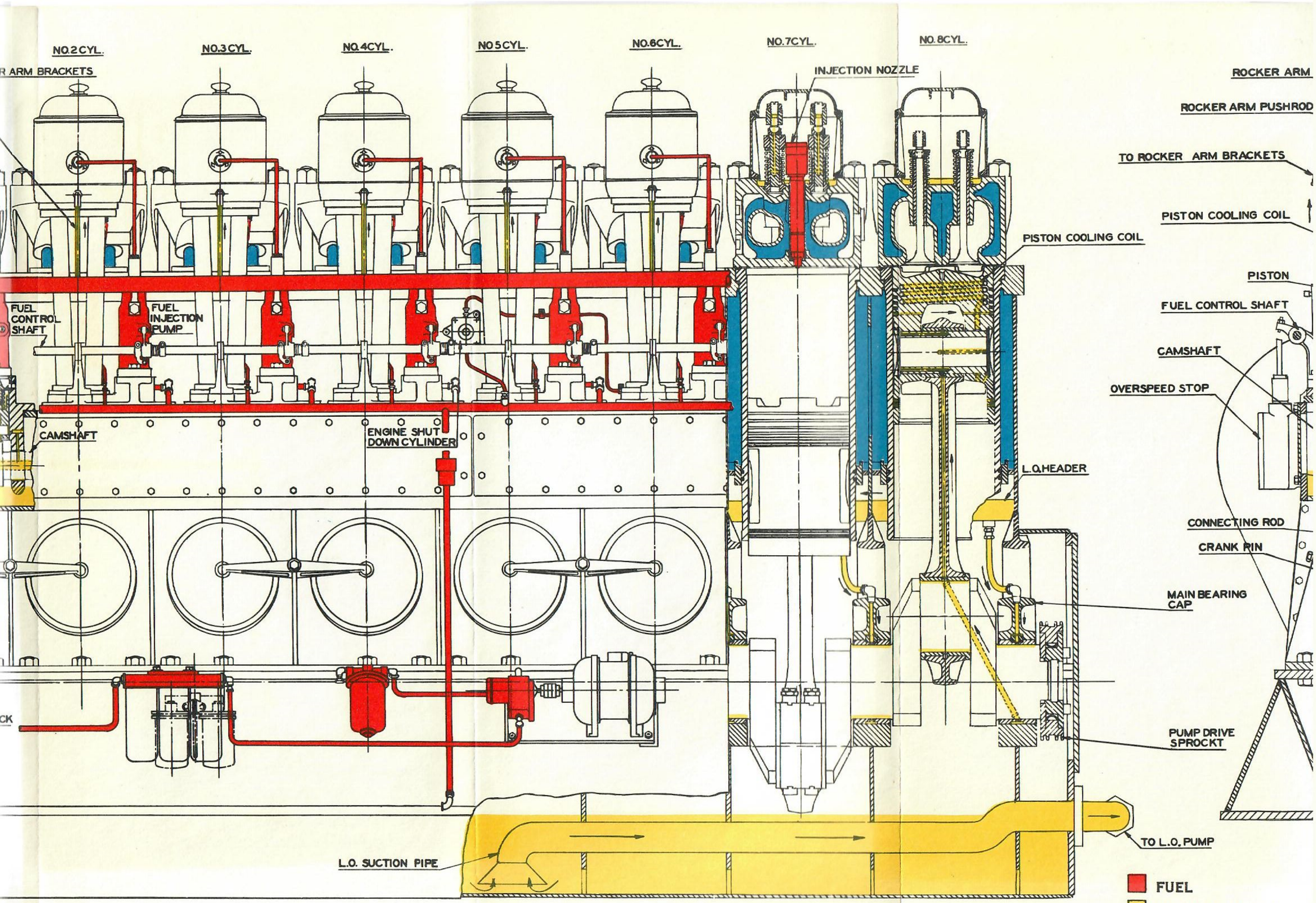
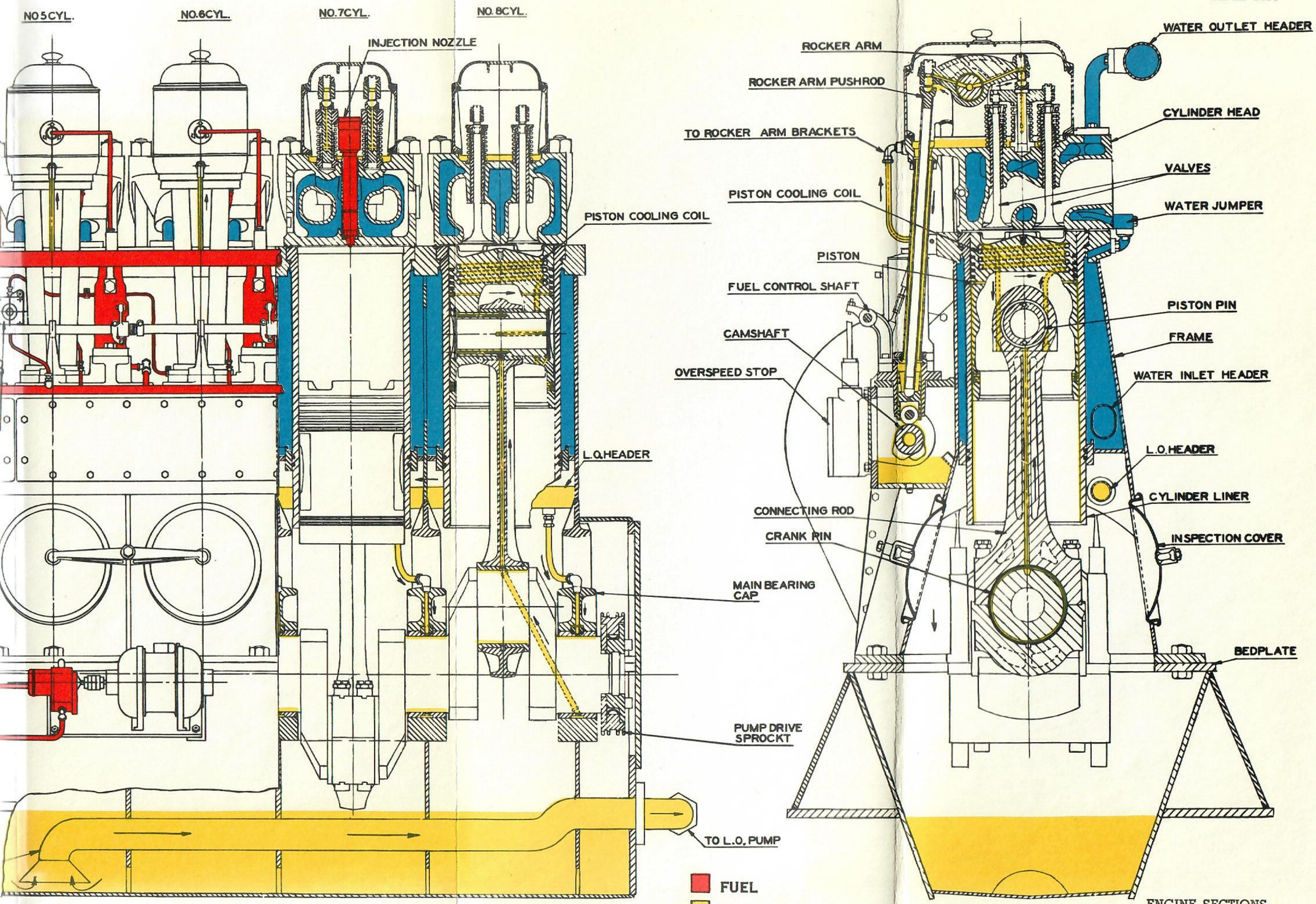

GOVERNOR
CHAIN LUBRICATION SPRAY
TO GOVERNOR DRIVE
FROM L.O. HEADER BLOCK
CHAIN LUBRICATION SPRAY
CAMSHAFT SPROCKET
OVER SPEED STOP DRIVE GEAR
L.O. HEADER BLOCK
L.O. HEADER
CHAIN LUBRICATION SPRAY
TO IDLER BRACKET
D 14014


NO.1 CYL.
NO.2 CYL.
NO.3 CYL.
NO.4 CYL.
TO ROCKER ARM BRACKETS
GOVERNOR
FUEL CONTROL SHAFT
FUEL INJECTION PUMP
CAMSHAFT
ENGINE SHU
DOWN CYLIN
FROM L.O. HEADER BLOCK
GOVERNOR DRIVE GEAR
FROM L.O. HEADER BLOCK
L.O. SUCTION PIPE


NO.2 CYL.
NO.3 CYL.
NO.4 CYL.
NO.5 CYL.
NO.6 CYL.
NO.7 CYL.
NO.8 CYL.
R ARM BRACKETS
INJECTION NOZZLE
ROCKER ARM
ROCKER ARM PUSHROD
TO ROCKER ARM BRACKETS
PISTON COOLING COIL
PISTON COOLING COIL
PISTON
FUEL CONTROL SHAFT
FUEL INJECTION PUMP
CAMSHAFT
OVERSPEED STOP
ENGINE SHUT DOWN CYLINDER
CAMSHAFT
L.O.HEADER
CONNECTING ROD
CRANK PIN
MAIN BEARING CAP
PUMP DRIVE SPROCKT
CK
TO L.O. PUMP
L.O. SUCTION PIPE
FUEL
LUBRICATING OIL
COOLING WATER



ENGINE SECTIONS

Figure 7

AIR INTAKE FILTER

The engine air intake filter and silencer is made up of a sheet metal and expanded metal housing containing two, three, or four removable elements filled with finely shredded copper. The oiled surfaces of the shredded copper remove dust from the intake air insuring a clean air supply to the engine.

MAINTENANCE

The maintenance of air filters consists of regular cleaning and re-oiling of the elements. Consult your Maintenance Chart and Maintenance Bulletins for schedule and cleaning procedure.

TURBOCHARGER

The Elliott Buchi turbocharger is a self contained unit comprising a gas turbine and a centrifugal blower mounted on a common shaft. The exhaust gas turbine utilizes the energy in the exhaust gases to drive the centrifugal blower. The blower furnishes all the air required by the engine at a low pressure thru the air intake manifold.

LUBRICATING OIL SYSTEM

The turbocharger is lubricated from the engine lubricating oil system. A reducing valve (set at 30 P.S.I.), a lubricating oil filter and a gauge are provided in the supply pipe to the turbocharger. The lubricating oil filter has a non-adjustable differential pressure relief valve set at 16 to 18 P.S.I. The lubricating oil pressure should not be less than 20 pounds, and this pressure must be reached within 12-15 seconds after the turbocharger starts to rotate. It is very important that the oil flowing to the turbocharger be in as clean a condition as possible. The lubricating oil filter cartridge must be changed as specified on your Maintenance Chart. If the lubricating oil pressure drops below 20 pounds it may be necessary to change the fitler cartridge more often. The maximum inlet temperature of the lubricating oil should not exceed 160° F. Discharge temperature should not be greater than 180° F.

COOLING WATER SYSTEM

The turbocharger is cooled by circulating the engine cooling water thru the turbine casing and the backplate. The water temperature rise thru the turbocharger should not exceed 30° F. and the maximum discharge temperature should not exceed 180° F. Before shutting down the engine it should be operated at idle approximately 10 minutes in order to dissipate as much heat as possible from the turbocharger.

Annually the plugs and water connections should be removed in order to clean any scale or sludge which has accumulated in the turbocharger jackets and piping.

A drain plug is provided on the bottom of the turbine inlet casing. This plug should be opened when the engine

is shut down for any length of time and left open until starting up again. This will prevent any condensate, or rain water from collecting in the turbine casing. If oil collects in the turbine casing check for an oil leak between turbine disk and the shaft.

AIR INTAKE MANIFOLD PRESSURE

A manometer, if provided, will indicate the pressure in the air intake manifold. At full load, full speed, the manometer should indicate a manifold pressure of 5½ to 7 pounds. An increase in pressure above normal indicates the engine is burning an excessive amount of fuel and adjustments should be made to correct the condition. A decrease in pressure below normal indicates that excessive dirt has collected on the impeller and diffuser, and the turbocharger should be cleaned. This might also be caused by restrictions in the air filter due to dirt or other impurities.

EXHAUST GAS TEMPERATURE

The maximum temperature of the exhaust gases at turbine inlet should not exceed 1000° F. An overload of 1100° F. may be permitted for not more than two hours. Excessive exhaust gas temperatures may be due to one or several of the following conditions:

1. Improper performance of fuel injectors.
2. Valves not seating properly.
3. Incorrect timing of valves or fuel injection.
4. Dirty air intake filters.
5. Dirt deposited on blower impeller and diffuser ring.

MAINTENANCE

The supercharged models of the Baldwin diesel engine are equipped with either the Elliott Buchi turbocharger (three or four inlet pipes) or the two inlet pipe turbocharger. These units are precision made and operate at very high speeds and temperatures. Tolerances are very closely maintained and all moving parts must be dynamically balanced and completely tested before being put into service.

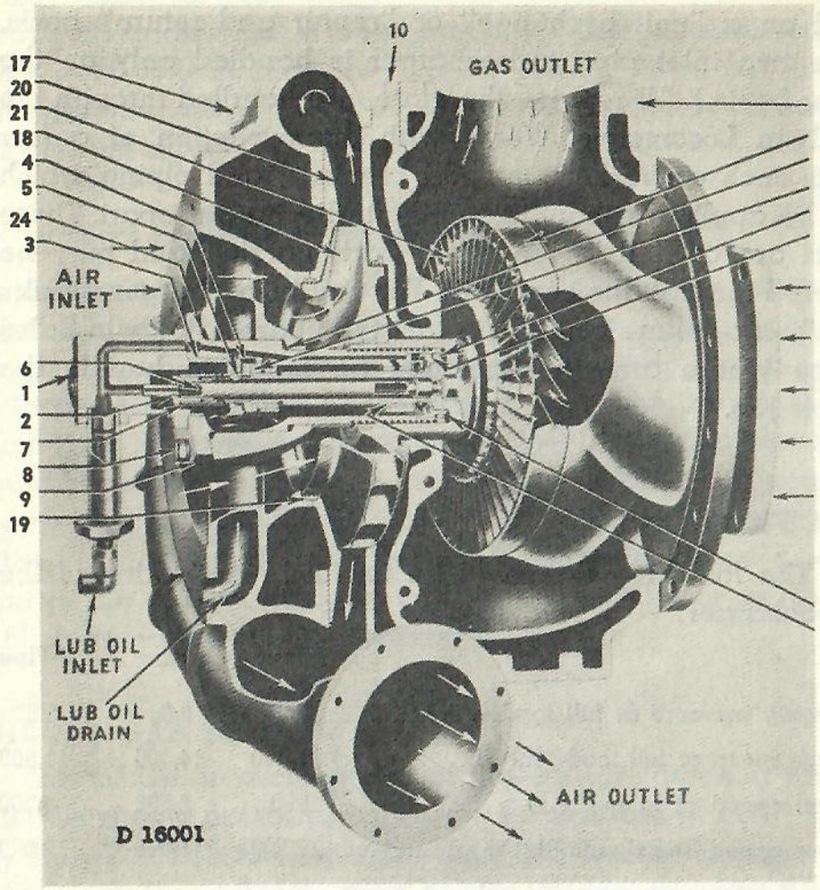
Because of the above features, turbochargers are handled on a "unit exchange" or "repair and return" basis. (The two inlet pipe turbocharger is handled only on the latter basis.) All repairs, therefore, are handled through the Baldwin Locomotive Works with the exception of a few parts such as gaskets, support brackets, and piping which can be applied without taking the turbocharger apart. These parts are carried in the spare parts catalog and may be ordered through the company. For any turbocharger repairs or when a failure occurs, contact the nearest Baldwin Sales Office where arrangements can be made to handle the repair job.

SPECIFICATIONS

The following data will be useful in inspection of the turbocharger:

	4-Pipe	3-Pipe	2-Pipe
Charging pressure at full load—P.S.I.	7.0	6.5	5.5
Blower speed at full load—R.P.M.	11,000	14,000	11,800
Blower speed at idle—R.P.M.	900	2,500	2,200
Blower speed—maximum R.P.M.	12,500	16,000	13,000
Approximate temperature of exhaust gases after turbine—°F.	855	835	800
Exhaust elbow temperature—°F.	850*	850*	850*
Maximum continuous exhaust temperature before turbine—°F.	1,000*	1,000*	1,000*
Maximum exhaust temperature before turbine (momentary)—°F.	1,100	1,100	1,100

*± 50° F.—acceptable variation.

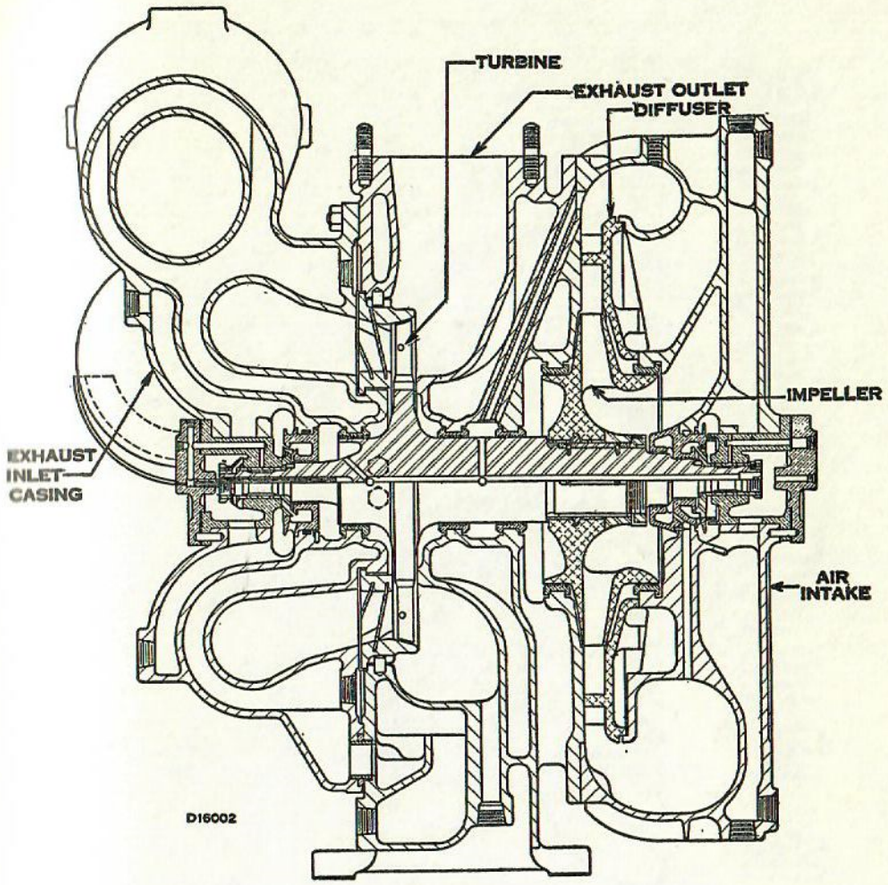


TURBOCHARGER
(3 & 4 Exhaust Pipe Type)

Figure 1

1. Bearing Support Cap
2. Special Nut
3. Thrust Bearing
4. Thrust Collar
5. Thrust Collar Key
6. Locking Tube
7. Compression Washer
8. Bearing Support Stud Nuts
9. Bearing Support
10. Backplate
11. Oil Baffle
12. Outer Bearing
13. Inner Bearing
14. Oil Baffle Nut
15. Neoprene Gasket
16. Turbine Casing
17. Blower Casing
18. Impeller
19. Inner Labyrinth Ring
20. Diffuser Ring
21. Turbine Disk
22. Nozzle Ring

23-24. Bearing Support Gaskets



TURBOCHARGER
(2 Exhaust Pipe Type)

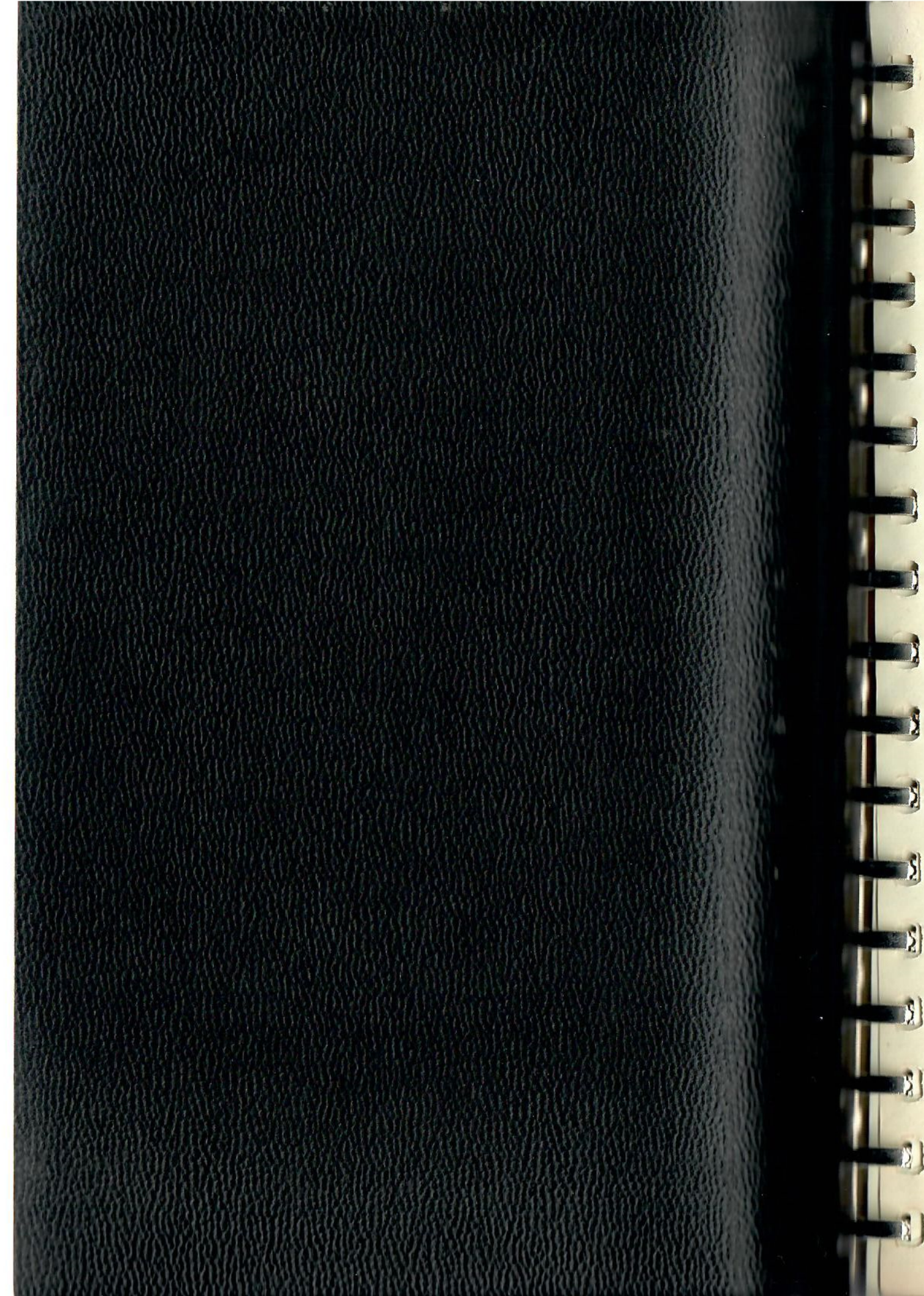



Figure 2